2023 DRAFT COASTAL MASTER PLAN

PLANNING TOOL METHODS AND RESULTS

ATTACHMENT G1

REPORT: VERSION 02

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COASTAL PROTECTION AND RESTORATION AUTHORITY

This document was developed in support of the 2023 Coastal Master Plan being prepared by the Coastal Protection and Restoration Authority (CPRA). CPRA was established by the Louisiana Legislature in response to Hurricanes Katrina and Rita through Act 8 of the First Extraordinary Session of 2005. Act 8 of the First Extraordinary Session of 2005 expanded the membership, duties, and responsibilities of CPRA and charged the new authority to develop and implement a comprehensive coastal protection plan, consisting of a master plan (revised every six years) and annual plans. CPRA's mandate is to develop, implement, and enforce a comprehensive coastal protection and restoration master plan.

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EXECUTIVE SUMMARY

Since the publication of the 2007 Coastal Master Plan, the Louisiana Coastal Protection and Restoration Authority (CPRA) has procured over $20 billion to support planning, engineering and design, and construction of hundreds of restoration and protection projects. Scientific understanding of coastal processes, how the coast will evolve in the future, and the effects of coastal investments continue to be incomplete. As such, the CPRA Planning Tool was developed to help formulate the 2012 Coastal Master Plan and was revised for the 2017 Coastal Master Plan. As part of the 2023 Coastal Master Plan, the Planning Tool was again updated to use more detailed modeling data, including a structure-based asset inventory, and to respond to new CPRA planning priorities. This report builds upon the preliminary methodology guide in Groves et al. (2021) *Planning Tool Overview,* to describe methods actually used to generate the results of the 2023 Planning Tool analysis. Major improvements described in this document include, but are not limited to: (1) annual estimation of project benefits, (2) development of two implementation periods (IPs) with an intermediate modeling step that considers initial restoration projects in the future landscape for the second period, (3) evaluation of a new land sustainability constraint, (4) consideration of sediment borrow costs, (5) optimization of a robust set of project alternatives to ensure good performance across considered scenarios, and (6) inclusion of an equity-based decision driver.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AAL .... AVERAGE AMOUNT OF ANNUAL LAND BUILT ABOVE/BEYOND FWOA
ADCIRC+SWAN .... ADVANCED CIRCULATION-SIMULATED WAVE NEARSHORE
AEP .... ANNUAL EXCEEDANCE PROBABILITY
B.. BILLION
BCR.. BENEFIT-COST RATIO
CLARA .... COASTAL LOUISIANA RISK ASSESSMENT MODEL
CSV .... COMMA-SEPARATED VALUE FILE
CPRA .... COASTAL PROTECTION AND RESTORATION AUTHORITY
DMDU .... DECISION MAKING UNDER DEEP UNCERTAINTY
E&D .... ENGINEERING AND DESIGN
EADD .... EXPECTED ANNUAL DAMAGE IN DOLLARS
EASD .... EXPECTED ANNUAL STRUCTURAL DAMAGE
ESLR .... EUSTATIC SEA LEVEL RISE
EWE .... ECOPATH WITH ECOSIM
FT .... FEET
FWOA .... FUTURE WITHOUT ACTION
GAMS .... GENERAL ALGEBRAIC MODELING LANGUAGE
HSI .... HABITAT SUITABILITY INDEX
ICM .... INTEGRATED COMPARTMENT MODEL
IP .... IMPLEMENTATION PERIOD
IPET .... INTERAGENCY PERFORMANCE EVALUATION TASKFORCE
K .... THOUSAND
LMI .... LOW-TO-MODERATE INCOME
M .... MILLION
M .... METERS
MT .... MEDIUM-TERM
MCDA .... MULTI-CRITERIA DECISION ANALYSIS
MIP .... MIXED-INTEGER PROGRAMMING
NRC .... NATIONAL RESEARCH COUNCIL

O&M .... OPERATIONS AND MAINTENANCE
PDT .... PROJECT DEVELOPMENT TEAM
PPD .... PROJECT DEVELOPMENT DATABASE
RDM .... ROBUST DECISIONMAKING
SQ KILOMETERS .... SQUARE KILOMETERS
SQ METERS .... SQUARE METERS
SQL .... STRUCTURED QUERY LANGUAGE
USACE .... US ARMY CORPS OF ENGINEERS

1.0 INTRODUCTION

Coastal Louisiana faces long-term sustainability challenges due to severe coastal land loss and increasing flood risk. For nearly six decades, national and state government agencies, state and local organizations, corporations, and citizen's groups have invested significant resources in ecosystem restoration and levee protection. Coastal Louisiana has experienced a net change in land area of approximately -4,833 km^2 from 1932 to 2016 (Couvillion et al., 2017). Tremendous impacts from the 2005 hurricanes re-emphasized that more action was required and would need to be coordinated as part of a comprehensive plan. Following the devastating 2005 hurricane season, the Louisiana State Legislature passed Act 8, which created the Coastal Protection and Restoration Authority (CPRA) and stipulated that CPRA develop a master plan to be updated regularly (every six years) to ensure that the state was effectively building on success and taking advantage of new science and innovation.

1.1 CHALLENGES IN FORMULATING A LONG-TERM MASTER PLAN FOR LOUISIANA

There are numerous challenges that CPRA is addressing to update its long-term Coastal Master Plan.

DIVERSE COMMUNITIES AND NATURAL RESOURCES

Coastal Louisiana is a working coast. It is home to over two million people and is endowed with a large diversity of natural resources, many of which support economic and recreational activities. The dynamic deltaic coast provides vital habitat to hundreds of aquatic and terrestrial species. The coast is also home to large cities and regional centers, such as New Orleans, Lake Charles and Thibodaux-Houma. Some of these are protected by significant existing flood control infrastructure constructed by the federal government, while others have no protection. Within the urban centers, communities face different amounts of risk and vulnerability to storms, with many people facing disproportionately high risks relative to their capacity to recover. There are also numerous rural and isolated communities that are highly vulnerable to storm surge-based flooding. Any decision that affects a community and the environment is subject to debate over goals, priorities, and resource allocation.

COMPLEXITY AND UNCERTAINTY

The coastal system is dynamic and interconnected. Many aspects of future change are highly uncertain. Drivers of change, such as rates of sea level rise, subsidence, and erosion; future hurricane activity; hydrologic fluctuations and trends; and the effects of future human activities are difficult to predict long-term, despite the best scientific understanding of these processes. The ecosystem, species, and societal responses to these drivers thus will remain difficult to predict. The specific effects that coastal investments in restoration or risk reduction projects could have on the coast are therefore similarly uncertain, and choices about how to address coastal issues need to consider this uncertainty.

WIDE RANGE OF OPTIONS TO ADDRESS CHALLENGES

There are many investments or projects that could be implemented to help address these challenges, each with different costs and potential effects on the coast. Options to reduce coastal land loss include projects that mechanically move sediment to rebuild land as well as more process-based approaches of diverting sediment-rich floodwaters to wetlands in need of sediment nourishment. Other projects target specific areas of need, including hydrologic and ridge restoration. Similarly, flood risk can be reduced by physical structures, such as levees and floodgates that are designed to block or reroute water. Nonstructural risk reduction measures, such as floodproofing or elevating structures, can reduce risk by increasing the resistance of structures to flooding. Voluntary acquisitions of property can also reduce risks by removing assets from areas subject to flooding. Some projects are best conceived as integrated projects that include different elements that work together to improve ecosystem function or reduce risk.

IDENTIFYING A ROBUST STRATEGY

Given the significant uncertainty over how the coast will change over time and the multitude of different approaches to improve ecosystem function and manage risks to flooding, a strategy optimized for one environmental scenario may perform poorly if another alternative future happens. A robust strategy would seek a set of projects to best address the coastal challenges however they manifest over the coming decades. Practically, this means first identifying a set of near-term projects that science and judgement suggest would provide the best contribution to sustaining land and reducing flood risk under specific assumptions about future conditions. Based on this analysis, CPRA can then identify the set of projects that are shown to perform well under different potential future conditions. Projects for later decades can then be selected similarly, based on how they interact with the first set of projects implemented. Consistent with the 6-year master planning cycle, projects selected for later implementation will be re-evaluated in future master plans, using updated models and information, ensuring that the best available information is considered prior to committing to a course of action. Together, these elements define a robust strategy for the master plan.

HARD DECISIONS

Louisiana faces hard decisions; there is no single solution that will solve every challenge facing the coast. Certain activities and ecosystems face greater sustainability challenges than others. In some cases, decisions to focus investment in some areas and not in others will need to be made. As with previous master plan efforts, CPRA is committed to using the best available science in a transparent manner to help inform these conflicting priorities and/or necessary investment tradeoffs for the 2023 Coastal Master Plan.

1.2 HOW THE PLANNING TOOL SUPPORTS THE COASTAL MASTER PLAN PROCESS

The 2007 Coastal Master Plan set a new course for Louisiana by defining high-level objectives to guide development of a comprehensive strategy. These objectives have been refined and added to in subsequent plans:

- **Flood Protection.** Reduce economic losses from storm surge-based flooding to residential, public, industrial, and commercial infrastructure.
- **Natural Processes.** Promote a sustainable coastal ecosystem by harnessing the natural processes of the system.
- **Coastal Habitats.** Provide habitats suitable to support an array of commercial and recreational activities coast wide.
- **Cultural Heritage.** Sustain the unique cultural heritage of coastal Louisiana by protecting historic properties and traditional living cultures and their ties and relationships to the natural environment.
- **Working Coast.** Promote a viable working coast to support regionally and nationally important businesses and industries.

The 2012 Coastal Master Plan (CPRA, 2012) introduced a new planning framework to formulate a 50-year, $50 billion investment plan. To guide the planning process, CPRA supported the development of systems models and a Planning Tool to evaluate and compare projects and formulate groups of projects (i.e., alternatives) objectively (Groves et al., 2012). In this framework, a suite of predictive models developed by CPRA are used to estimate how the coastal system and associated flood risks would change over the next 50 years under different scenarios, reflecting uncertainty about key drivers, such as sea level rise. The models also estimate the effects of different restoration and risk reduction projects on a wide range of landscape-, ecosystem-, and risk-related outcomes. CPRA then used the Planning Tool in an iterative process with stakeholders to evaluate differences among various alternatives and define the potential projects to include in the draft 2012 Coastal Master Plan.

Between the 2012 and 2017 plans, CPRA secured funding for and implemented projects on the ground using the 2012 Coastal Master Plan analysis as a guide. Projects constructed or funded for construction before the 2017 plan were added to the Future Without Action (FWOA) landscape and removed from consideration as candidate projects for the 2017 Coastal Master Plan analysis (CPRA, 2017). However, in order to continue providing guidance to support flexibility across various funding sources with different goals and rules, CPRA chose to maximize benefits for a $50 billion plan over 50 years again, adding new candidate projects for consideration. The Planning Tool Team then re-estimated coastal conditions out 50 years, based on the new conditions reflecting five prior years of changes and project implementation. The team then re-evaluated and re-prioritized a wide range of risk reduction and restoration projects across updated future scenarios (Groves & Panis, 2017).

The 2023 Coastal Master Plan continues this iterative process. As with the previous applications, the Planning Tool assisted CPRA in reviewing model projections of future conditions, compared estimated effects of risk reduction and restoration projects, and proposed alternatives composed of individual projects for consideration.

1.3 PURPOSE OF THIS REPORT

This report describes the planning framework and Planning Tool, details the methodology, and describes how it has selected potential projects for inclusion in the draft plan. The Planning Tool Team designed the report as an attachment to the 2023 Coastal Master Plan. The intended audience of the report includes CPRA planners, public decision-makers, community stakeholders, and any reader of the 2023 Coastal Master Plan interested in better understanding the technical details of the Planning Tool analysis.

1.4 ORGANIZATION OF THIS REPORT

There are seven subsequent sections in this report. Section 2.0 describes how the Planning Tool Team applied the revised methodology to the improved data. Section 3.0 gives an overview of the restoration and risk model data inputs, including the FWOA results, project attributes, and optimization constraints. Section 4.0 compares project effects and their cost-effectiveness. Sections 5.0 and 6.0 then formulate and evaluate alternatives. Section 7.0 describes how the Planning Tool supports master plan deliberations. Last, Section 8.0 concludes with recommendations for potential future analysis.

In addition, Section 9.0 provides references and Section 10.0 has a table of alternatives tested alongside their attributes.

2.0 METHODOLOGY

Since the publication of the 2007 Coastal Master Plan, CPRA has procured over $20 billion to support planning, engineering and design, and construction of hundreds of restoration and protection projects. Scientific understanding of coastal processes, how the coast will evolve in the future, and the effects of coastal investments continues to improve. As such, CPRA has continued to invest in data, modeling, and the Planning Tool. CPRA's planning framework combines two sets of analytic capabilities: integrated predictive models of the coastal system and the Planning Tool. Together, they iteratively support the development of the master plan.

Earlier versions of the Planning Tool are described in Groves, Panis, and Sanchez (2017); Groves and Sharon (2013); Groves, Sharon, and Knopman (2012); and CPRA (2012) among other sources. Figure 1 illustrates the framework in flowchart form, which has remained conceptually the same since 2012. This report builds upon and revises an introduction to the model and intended improvements for the 2023 Coastal Master Plan found in Groves, Panis, and Wilson (2021).

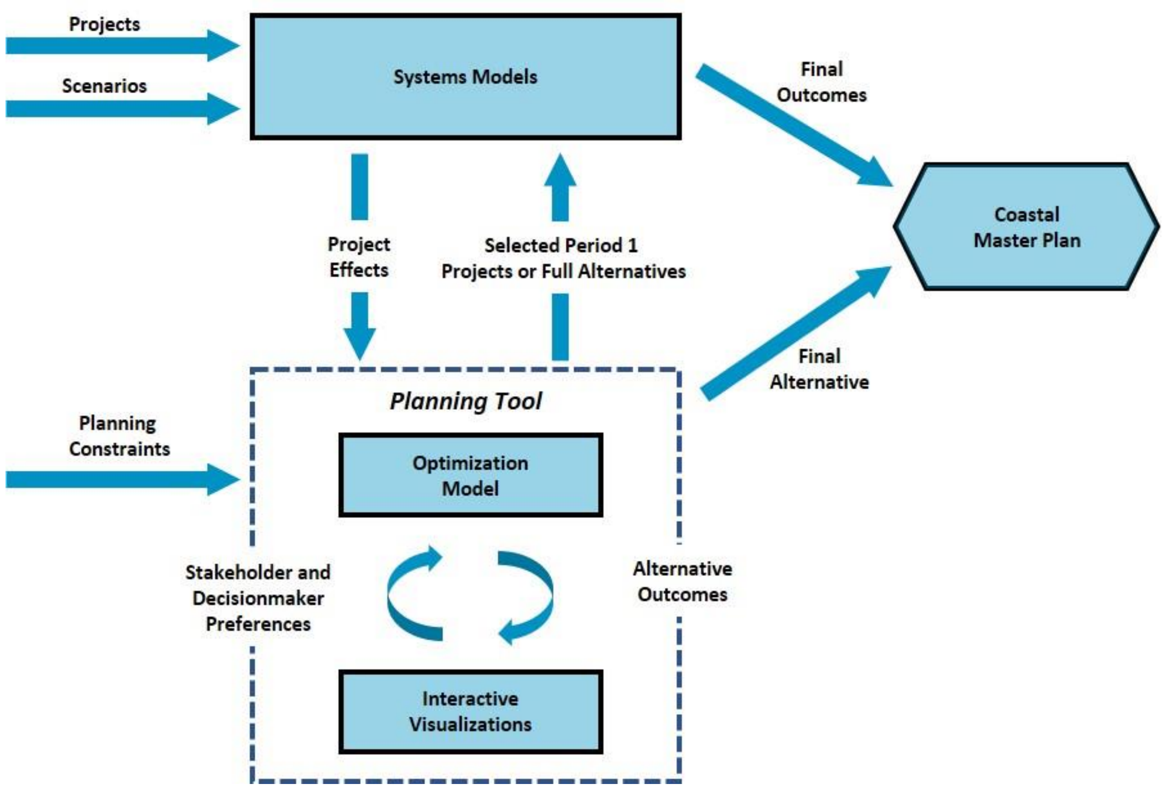

Figure 1. CPRA analytic framework. Based on Groves and Sharon (2013).

The process begins at the top left of the flow chart by using a set of predictive models to evaluate how proposed coastal restoration and risk reduction projects would individually affect the coast over the next 50 years relative to FWOA for multiple future scenarios. Specifically, the systems models (represented in aggregate by the top center box in Figure 1) estimate the effects that each project would have on the creation of average annual land; on future storm surges, waves, flooding, and flood damage; and on ecosystem characteristics, including habitats for different aquatic and land-based species. Additional calculations provide rough assessments of impacts on navigation, communities, industry, and other key assets.

For restoration projects, the Integrated Compartment Model (ICM) analyzes landscape and ecosystem performance under different environmental scenarios. It estimates hydrodynamic changes and the response by the land-water interface as well as vegetation typologies (see Appendix C: Use of Predictive Models in the 2023 Coastal Master Plan). A set of Habitat Suitability Indices (HSIs) for 13 fish and wildlife species (some analyzed for multiple life stages) are integrated into the ICM for the 2023 Coastal Master Plan and provide estimates of a variety of aquatic and terrestrial species habitat (see Attachment C10: 2023 Habitat Suitability Index (HSI) Model).

On the flood risk side, the Advanced Circulation-Simulated Wave Nearshore model (ADCIRC+SWAN) estimates storm surge and waves for a large set of simulated tropical storms and hurricanes. The surge and wave results then serve as input to the Coastal Louisiana Risk Assessment Model (CLARA), which translates storm surge into flood depths, as influenced by levees and other structural risk reduction projects and using future landscapes predicted by the ICM (see Fischbach et al., 2021). The CLARA model then calculates the resultant damages to a wide array of coastal assets. By evaluating the results of different modeled storms, CLARA computes statistical flood damage metrics.

The restoration and risk model results serve as inputs to the Planning Tool, a computer-based decision support software system, along with planning constraints such as amount of potential funding, decision-maker goals, and stakeholder preferences. The Planning Tool uses optimization to identify alternatives comprising the projects that build the most land and reduce the most storm surge-based flood risk (measured by both damage in dollars as well as structure equivalents), while meeting funding and other planning constraints. As an additional output, the Planning Tool generates interactive visualizations that summarize information about individual projects and alternatives.

As the last step, the projects selected by the 2023 Draft Coastal Master Plan alternative selected by the Planning Tool are used to rerun the predictive models of various teams to estimate the effects on the coast so as to solicit stakeholder feedback in spring 2023.

2.1 THEORETICAL BASIS

The Planning Tool brings together several well-established planning methodologies in a customized way to meet Louisiana's planning needs, including elements of Multi-Criterion Decision Analysis (MCDA) and Robust Decision Making (RDM) within an overarching deliberation-with-analysis process to support complex environmental planning challenges (National Research Council, 2009). This approach uses data and models not to determine a specific course of action, but rather to help articulate a range of potential outcomes among many different courses of action over several plausible futures to support stakeholder and decision-maker deliberations.

The Planning Tool selects projects to maximize the restoration goal and weighted risk goals of the coastal master plan while satisfying a range of constraints, the collection of which is known as an alternative. MCDA is a standard approach to defining alternatives that conform to a set of preferences, as reflected by a corresponding set of weights (see Huang et al., 2011 for a review of relevant literature and Linkov & Moberg, 2011 for applications and case studies). Standard MCDA presents several challenges when applied to unique aspects of Louisiana's coastal planning problem. For example, the Planning Tool can evaluating interactions, synergies, and conflicts among different projects on a limited basis, but the complex context makes it nearly impossible to:

- Develop quantifiable coastal performance metrics that can be placed on a consistent scale for comparison,
- Interpret the meaning of a single objective function comprised of tens of different metrics, and
- Derive weights for each metric that represent the wide range of stakeholder views.

The Planning Tool, therefore, uses a simplified MCDA methodology. Rather than including all decision drivers within an objective function, the Planning Tool uses set of broken down, easily understood objective function (Romero, 1991). The Planning Tool then used standard mixed-integer programming (MIP) methods to maximize the objective function subject to funding and other planning constraints (Schrijver, 1998).

To address the significant uncertainty in estimating future coastal conditions, the Planning Tool supports the comparison of projects and formulates alternatives based on estimates of different environmental scenarios. RDM techniques help compare the various alternatives as well as suggest robust, adaptive alternatives (see Marchau et al., 2019 for an overview of RDM within the context of other decision-making under uncertainty, or DMDU, approaches). Specifically, RDM helps identify near-term projects for implementation and specific pathways for future investment based on the evolution of future conditions.

For restoration projects, the 2023 Planning Tool used the projects in the selected alternative from Implementation Period 1 (IP1) as an input to predict the effects of projects in Implementation Period 2 (IP2). The remaining candidate projects eligible for selection in second IP (Years 21-50) are then optimized across environmental scenarios and used to generate another set of alternatives, subject to decision-maker- and stakeholder-imposed constraints.[1] Section 2.2 below details additional methodological improvements.

2.2 MODEL EXTENTS AND GEOSPATIAL RESOLUTION

The ICM calculates and supplies to the Planning Tool a wide range of ecosystem metrics including the Average amount of Annual Land (AAL) built above FWOA (in square meters), which is used as the restoration decision driver. Other metrics include habitat area by species and area by wetland types. The ICM aggregates results up to the level of 25 ecoregions (see Figure 2) — defined to have similar geomorphology and ecological function — and the CPRA Team provides data in yearly increments from initial conditions to Year 50 to the centralized Project Development Database (PDD).

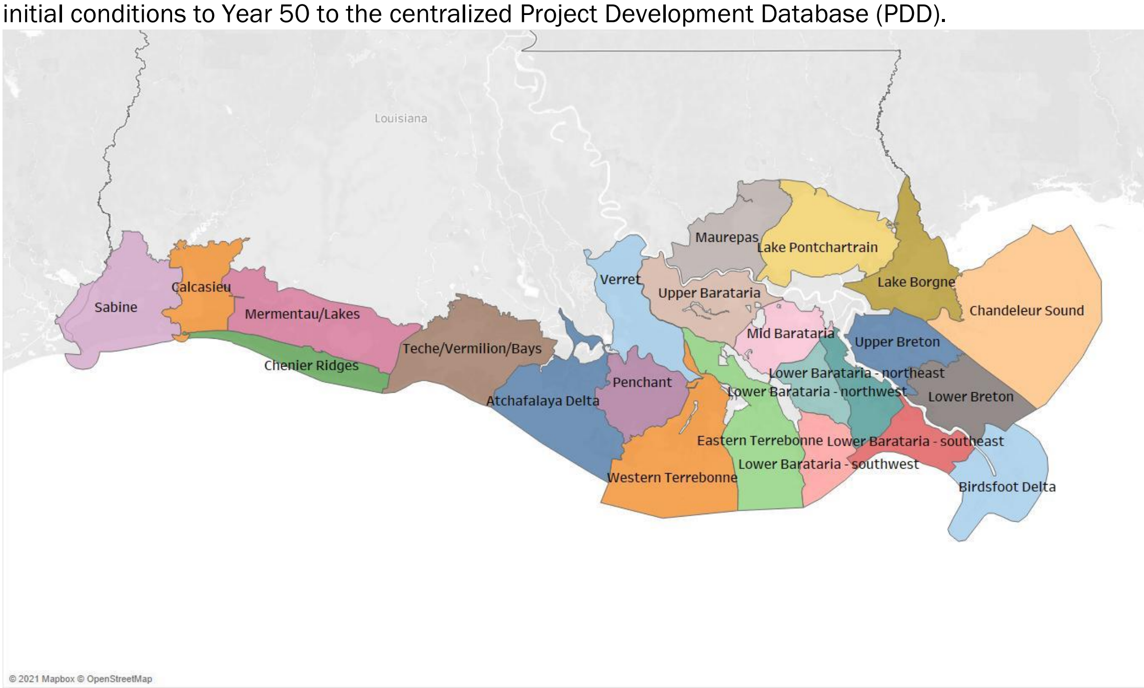

Figure 2. Ecoregions for 2023 Coastal Master Plan.

The Risk Assessment Team reports CLARA model results to the Planning Tool in terms of expected annual damage in dollars (EADD), expected annual structural damage (EASD), and the level of

[1] The risk analysis did not include this interim modeling step. See Section 3.5 for more details.

exposure for groups of assets (by depth) via the PDD. While the CLARA model generates additional probabilistic calculation details, the Planning Tool analysis uses and visualizes only the mean statistics when evaluating projects and formulating alternatives.

The Risk Assessment Team aggregates EADD and EASD results at the master plan community level. The team identified 204 communities using parish or municipal boundaries that were further categorized based on the community's location either inside or outside of existing structural protection, resulting in 291 distinct project geographic areas eligible for nonstructural investments (out of a possible 344 communities total) as shown in Figure 3. A major enhancement for the 2023 Coastal Master Plan was CLARA's structure-level inventory that generated risk data for six different asset types. These asset types were: single-family homes, multi-family housing, commercial and industrial, other structures (civic, educational, etc.), and nonstructural assets (roads, etc.). The Planning Tool analysis only used all asset types combined so as to simplify the decision driver logic.

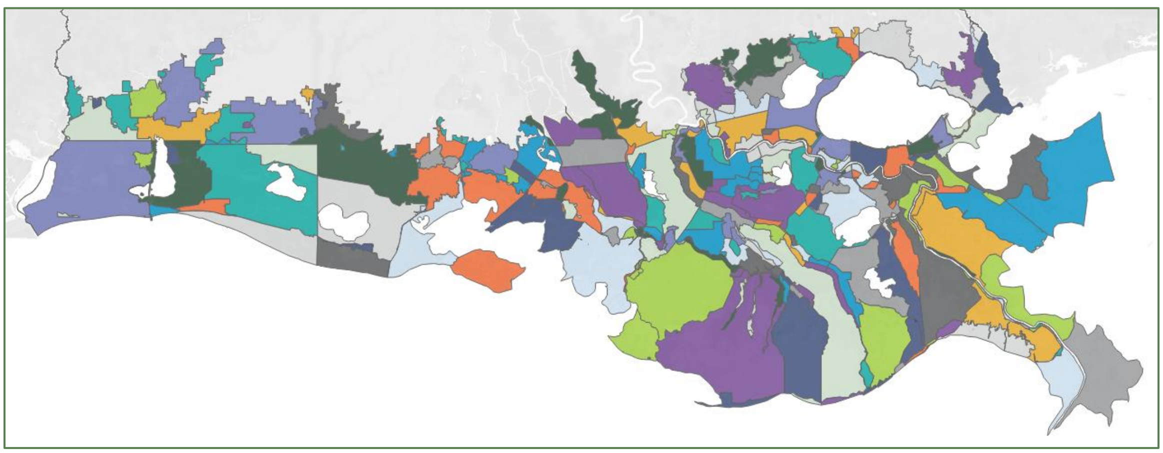

Figure 3. CLARA master plan communities.

2.3 SCOPE OF AND IMPROVEMENTS TO ANALYSIS

At the request of CPRA, the Planning Tool Team updated the tool's calculations to take advantage of advancements in the predictive models and improved interactive visualizations to account for new planning considerations. The major updates include:

- Greater temporal project benefit resolution from twice-in-50-years to annually
- Reduction in project IPs from three to two — Years 1 to 20 and Years 21 to 50
- Exploration of additional decision drivers to account for equity in risk assessment
- Development of new environmental scenarios

There are several other minor updates based on the data inputs and their structure that we address within the context of other topics in this document. For example, Section 3.4 details a reconfiguration of sediment borrow costs.

TIME HORIZON AND GRANULARITY

The Planning Tool evaluates projects and alternatives over a 50-year horizon, starting from an initial condition, representing 2020, out to 50 years into the future. For the 2017 Coastal Master Plan, the Planning Tool evaluated the effects of projects twice during the planning period — in Years 20 and 50 for restoration projects and in Years 25 and 50 for risk reduction projects. When formulating restoration alternatives, the Planning Tool maximized an objective function subject to funding, sediment, and other constraints. For the restoration alternatives, this was problematic because modelled project benefits varied over time considerably, and thus the timing of benefit peaks and troughs relative to the 20- and 50-year time periods could favor some projects over others.

For the 2023 Coastal Master Plan, the ICM output is provided in yearly increments, whereas the Planning Tool interpolates decadal CLARA data (see Section 3.6). This represents a change from 2012 and 2017, when projects were selected based on data for longer time intervals and benefits were shifted over time from IP1 to IP2. While this remained the case for 2023 Coastal Master Plan risk projects, which have fixed characteristics and the hazard exposure changes over time, restoration had an intermediate modeling step in which candidate IP2 projects were remodeled on a landscape assumed to have selected IP1 projects (see Figure 4).

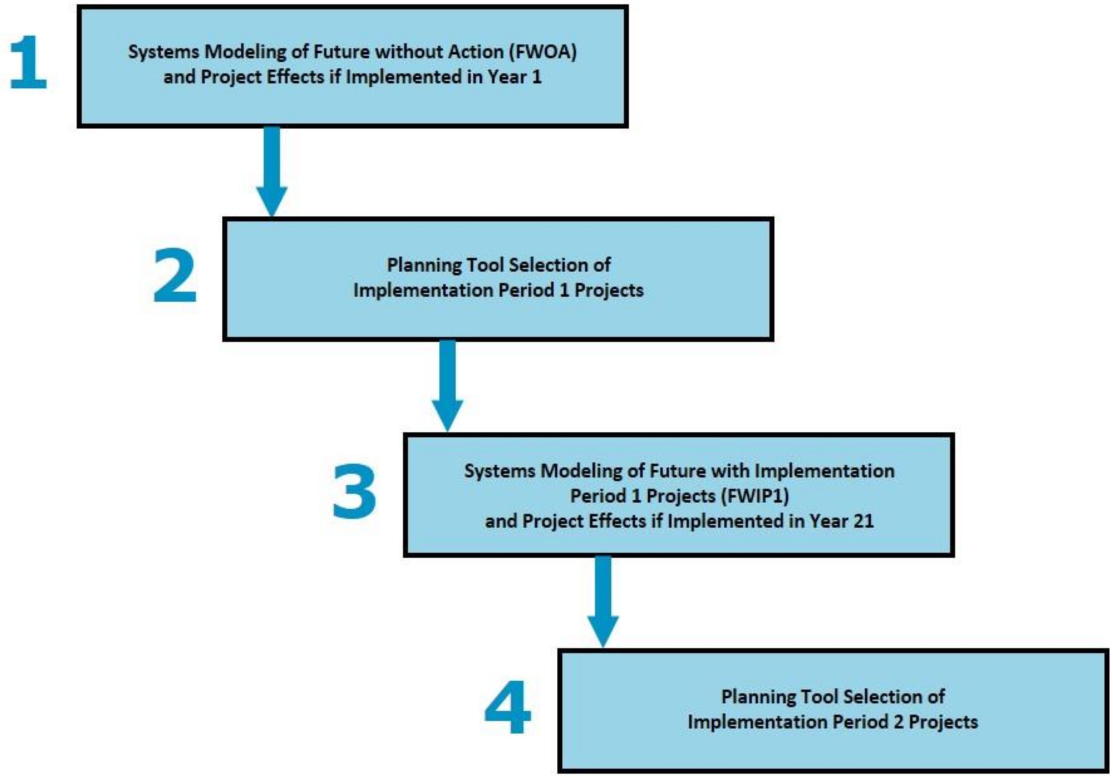

Figure 4. Four-step modeling and Planning Tool process to define a restoration alternative. Note intermediate step 3 was not done for risk reduction.

DECISION DRIVERS AND OBJECTIVE FUNCTIONS

The Planning Tool evaluates projects and outcomes based on a large set of metrics that are related to the five master plan objectives listed in the introduction above. For the 2012 and 2017 master planning process, CPRA defined two factors as decision drivers — total land area in Year 50 and the EADD of flood risk reduction. CPRA used the land and risk decision drivers to guide the alternative formulation because they are key requirements for all five of the master plan objectives, are well understood, and were shown to simplify the analysis without losing the flexibility for refining the plan. The CPRA Team continued this approach for the 2023 Coastal Master Plan.

The 2023 Planning Tool evaluated and implemented a new restoration objective function over the entire 50-year period – the Average amount of Annual Land built above and beyond FWOA (AAL). This approach considers fluctuations in the benefit stream over time and allows projects that provide substantial benefits that may yet diminish by Year 50 to compete better for funding. However, the 'balance' between near-term and long-term benefits that was central to project selection for the 2012 and 2017 Coastal Master Plans is no longer present. For example, it is conceivable that project selection using the continuous benefit stream could result in an alternative with no net benefit at Year 50 or near the end of the planning period.

As such, the 2023 Planning Tool also tested the concept of land sustainability – that landscape change is minimized and there is continuity to the existence of land – that is central to the master plan. For example, Master Plan Objective #2 is to "Promote a sustainable coastal ecosystem by harnessing the processes of the natural system." Therefore, for 2023, the Planning Tool also tested an alternative objective function that selected projects based preferentially on their AAL creation in the final decade and imposed a constraint to exclude projects that had negative AAL in Years 41-50 to ensure that land building was sustainable. As implemented, the Planning Tool's definition of sustainability, therefore, is that there is not net land loss at the end of the modeling period as sea level rise and subsidence increase. The results of the analysis, and the decision not to use land sustainability as a constraint, at least in the case of the 2023 Planning Tool, is described further in Section 5.4.

For risk reduction alternatives, the Planning Tool the 2012 and 2017 Coastal Master Plan metric of EADD, which monetizes impacts ranging from physical destruction to lost inventory, but also newly implements EASD, or how many structure equivalents are impacted by flooding and to what degree.[2] CPRA's goal by including EASD in addition to EADD is to better reflect equity considerations in risk reduction investments. For example, assuming the same square footage cost and exposure of two single-family houses, the EADD metric would lend more weight to avoided damages to the larger home, whereas EASD considers the two homes equally. In this way, EASD preferentially treats the utility function of a unit of housing. Similarly, one commercial or industrial facility with a high assessed value may have the same EADD metric as a portion of a neighborhood of single-family homes, whereas the neighborhood would have a higher EASD value for that exposure. By including both terms in the objective function, the Planning Tool can now balance between the traditional value-based approach for assessing risk with newer equity-aware approaches. The Planning Tool and CPRA Team jointly determined the weighting of the EASD term relative to average annual EADD reduction using modeled project effects as a key part of the 2023 analysis. For example, if EADD and EASD are weighted 50/50, this implies that CPRA equally values both monetary and functional value of a given structure. The CPRA Team iterated with the Planning Tool Team on how to operationalize this objective function as a part of developing IP1 risk reduction alternatives, described further in Section 6.2.

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[2] The damages described by the same structure equivalent number may vary widely. For example, damage of 100 single-family home structure equivalents may represent either 100 homes completely destroyed, or 1,000 homes only 10% damaged.

ENVIRONMENTAL SCENARIOS AND UNCERTAINTY ANALYSIS

For the 2023 Coastal Master Plan, scenarios and uncertainty analyses are used to evaluate uncertainty about the future. The scenarios relate to environmental drivers that affect future landscapes predicted by the ICM, which in turn affect ecosystem function and flood risk from tropical cyclones. CPRA defined two environmental scenarios that all teams use to evaluate FWOA conditions as well as future with project conditions for both risk reduction and restoration projects (see Appendix B: Scenario Development and Future Conditions). The Planning Tool formulates alternatives for each of the two scenarios and informs the formulation of a single final robust alternative – one that would perform well across both scenarios. The scenarios are based on variations of the following six variables established through data analysis and a review of the literature (see Appendix B: Scenario Development and Future Conditions):

- Eustatic Sea Level Rise (ESLR)
- Subsidence
- Precipitation
- Evapotranspiration
- Tributary flows
- Tropical Storm Intensity

Table 1 summarizes the differences between the two environmental scenarios.

Table 1. Environmental Scenarios for the 2023 Coastal Master Plan

SCENARIO	ESLR (METERS PER 50 YEARS) *	SUBSIDENCE	PRECIPITATION, EVAPOTRANSPIRATION, TRIBUTARY FLOWS	TROPICAL STORM INTENSITY
LOWER (S07)	0.5	DEEP SUBSIDENCE + 1ST QUARTILE OF SHALLOW SUBSIDENCE	RCP 4.5 50TH PERCENTILE	+5% INCREASE
HIGHER (S08)	0.77	DEEP SUBSIDENCE + MEDIAN OF SHALLOW SUBSIDENCE	RCP 4.5 50TH PERCENTILE	+10% INCREASE

* RATE OF CHANGE IS NOT LINEAR

Additional analysis with the Planning Tool could have been performed through sensitivity analysis over assumptions related to:

- Structural Protection Project Fragility and Pumping Capacity — two assumptions about assumed fragility of the existing and future structural protection systems (i.e., levees and walls) as well as three assumptions about assumed pumping capacity in low-lying and levee-protected areas

- Project Costs — different assumptions about the costs of projects
- Land Building Certainty — different assumptions about how confident the landscape model is about land building

These analyses are yet to be conducted. In addition, as land building certainty has not yet been evaluated, this document discusses its importance in Section 8.0 as a direction for future analysis.

LEVEE FRAGILITY AND PUMPING CAPACITY

Estimates of future risk depend on assumptions about the fragility of the structural risk reduction systems (Fischbach et al., 2021 & Johnson et al., 2021). To simplify analysis, CPRA directed the Planning Tool Team to assume fragility consistent with the USACE Interagency Performance Evaluation Task Force (IPET) low scenario, which allows breaches to occur at times other than peak surge along each levee segment.

Similarly, the CLARA model has three assumptions about pumping capacity for low-lying and levee-protected areas, ranging from 100% capacity to no pumping, and a mid-range 50% capacity scenario that envisions either mechanical damage or other system design failures. CPRA directed the Planning Tool Team to make a conservative assumption, and the alternative formulations only used the 50% capacity scenario in order to simplify analysis.

To understand the sensitivity of project effects to both levee fragility and pumping capacity, see Appendix C: Use of Predictive Models in the 2023 Coastal Master Plan and Appendix E: Overview of Improvements to Risk Modeling (ADCIRC+SWAN, CLARA) for 2023.

PROJECT COST UNCERTAINTY

There is always uncertainty when estimating the costs of projects. In standard construction planning, this is handled by including a contingency factor, generally specified as a percentage of the estimated cost. For the master plan, the scale, scope, and novelty of the projects suggest that the uncertainty could be larger than would be reasonably reflected by a single or fixed contingency factor. The Planning Tool is configured to consider different uncertainty factors for different types of projects as part of a sensitivity analysis. For example, structural projects had three costs uploaded to the PDD associated with scenarios developed by other teams (see Appendix F: Project Concepts). CPRA directed the Planning Tool to assume the mid-range cost for alternative formulations to simplify the analysis.

For the 2023 Coastal Master Plan, restoration projects may have a range of costs, with typically the largest uncertainty being the relative availability of sediment at the time of construction. The PDD assigns one or more specific sources from which projects that require sediment can acquire it. As described below in Section 3.4, sediment for one project may come from multiple sources and different costs are incurred depending on the source used by a project. This information is also stored in the Planning Tool database for use by the optimization routine. Note that for 2017, sediment costs were independent of the source and thus included in the predetermined "project costs".

2.4 DATA STRUCTURE

The Planning Tool consists of three discrete elements – a database, an optimization model, and an interactive visualization package. External resources available to the Planning Tool include the PDD, a PostgreSQL database that consists of structured input data tables with query-derived predictive model outputs, and user specifications of alternatives (see Figure 5). For the 2023 Planning Tool, all this information is stored in a structured SQLite database with metadata detailing the origin and date of the data. The SQLite database format is also portable, allowing it to be transferred to other systems for archiving or analyses, consisting of a series of tables containing data structured around a defined variable naming convention. Key variables include:

- Project attributes – information about projects
- Outcomes – estimates of coastal conditions (for specific metrics) without and with the implementation of projects by predictive models
- Constraints – information about limitations that affect how projects can be selected as part of an alternative (e.g., mutually exclusive or prerequisite projects as well as land sustainability or other metrics)
- Alternative formulation specifications – descriptions of how the Planning Tool is configured for each alternative
- Alternative results – estimated outcomes for each alternative

The following chapter will explore each of these data types.

The Planning Tool's SQLite database pulls from the CPRA PostgreSQL database and ingests the specification of alternatives. Using an optimization model developed in General Algebraic Modeling Language (GAMS),[3] the Planning Tool selects projects for each IP to generate an alternative. The attributes and effects of these alternatives are then returned to the SQLite database and exported to Comma-Separated Value files (CSVs) via Python code. The Planning Tool Team then pulls the CSVs from local files and develops interactive visualizations using Tableau, a business information analytic platform capable of easily and flexibly connecting cross-referenced databases. The Planning Tool

[3] GAMS (General Algebraic Modeling System) is a high-level modeling system. It consists of a language compiler and a stable of integrated high-performance solvers. CPLEX is used in this application.

Team packaged the visualizations in workbooks (or generated specifically requested data tables) and made each of the in-progress development versions available via Tableau Public. Given the feedback of CPRA, the Planning Tool Team can fix any issues with the PDD, change the specification alternatives, tweak the GAMS optimization parameters, troubleshoot Python code, or adjust cross-database relationships in Tableau.

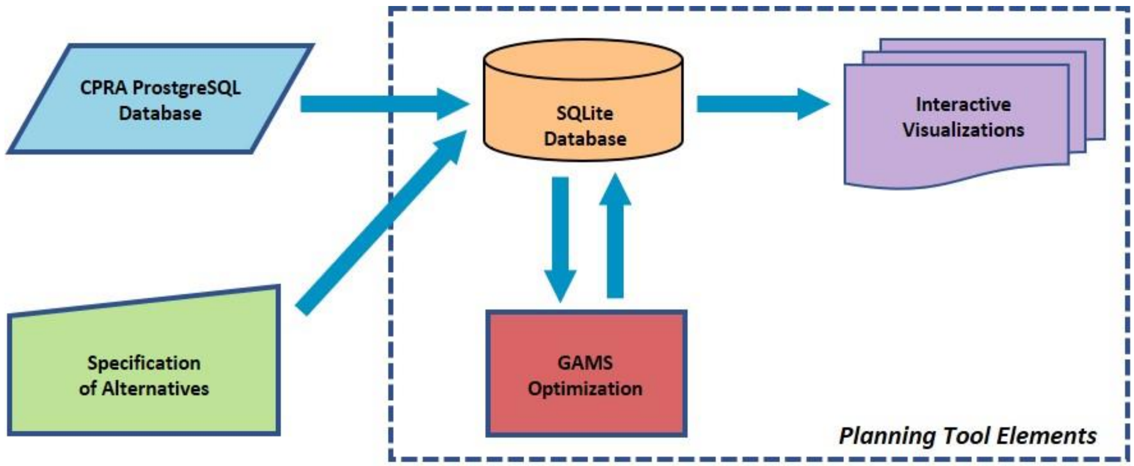


Figure 5. Planning Tool data architecture.

3.0 RESTORATION AND RISK MODEL DATA INPUTS

3.1 FUTURE WITHOUT ACTION CONDITIONS

The predictive models estimate FWOA coastal conditions (i.e., conditions without projects on the landscape) for each environmental scenario, and summarize this information for the Planning Tool. As described in Section 2.0, the ICM aggregates ecosystem outcomes by 25 ecoregions and provides annual data to Year 50. In contrast, CLARA aggregates risk outcomes for 291 communities and provides decadal data that the Planning Tool then linearly interpolates annually. In the case of restoration, the ICM modeled ten landscape and ecosystems characteristics using AAL. The Planning Tool's interactive dashboards, such as the one shown in Figure 6, allow for users to select either environmental scenario, drill down by ecoregion, or segment by annual time slice. The Planning Tool Team developed similar displays for EADD and EASD risk FWOA (see Figure 7 and Figure 8) that allow for exploration by environmental scenario, levee fragility, pumping assumptions, asset type, master plan community, or decadal time interval.

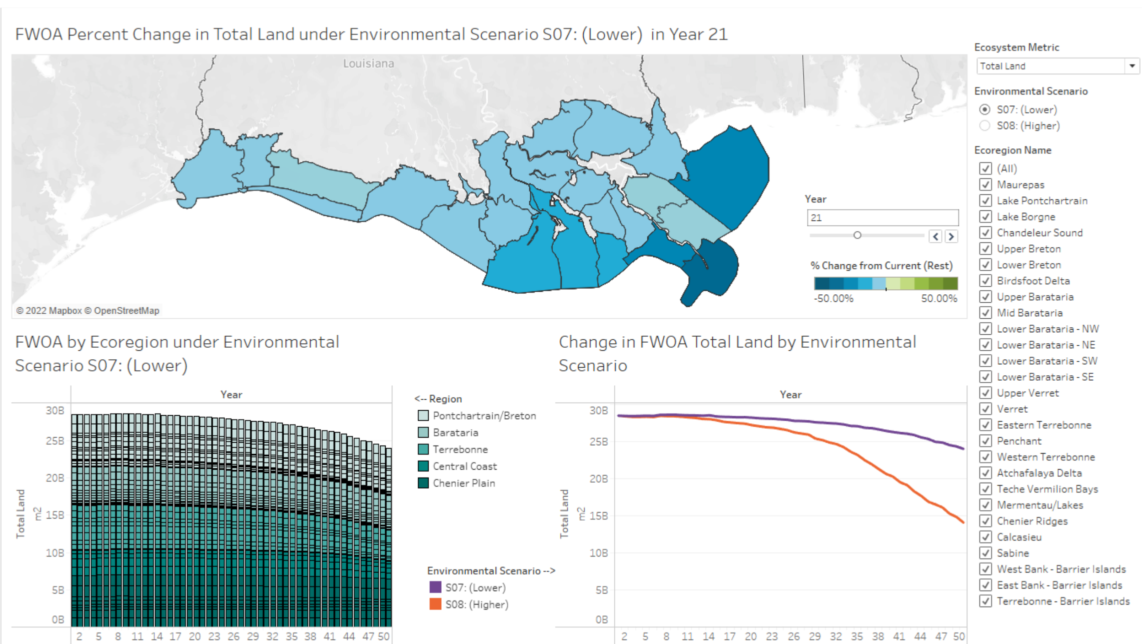


Figure 6. FWOA total land restoration metric for the lower environmental scenario in Year 21.

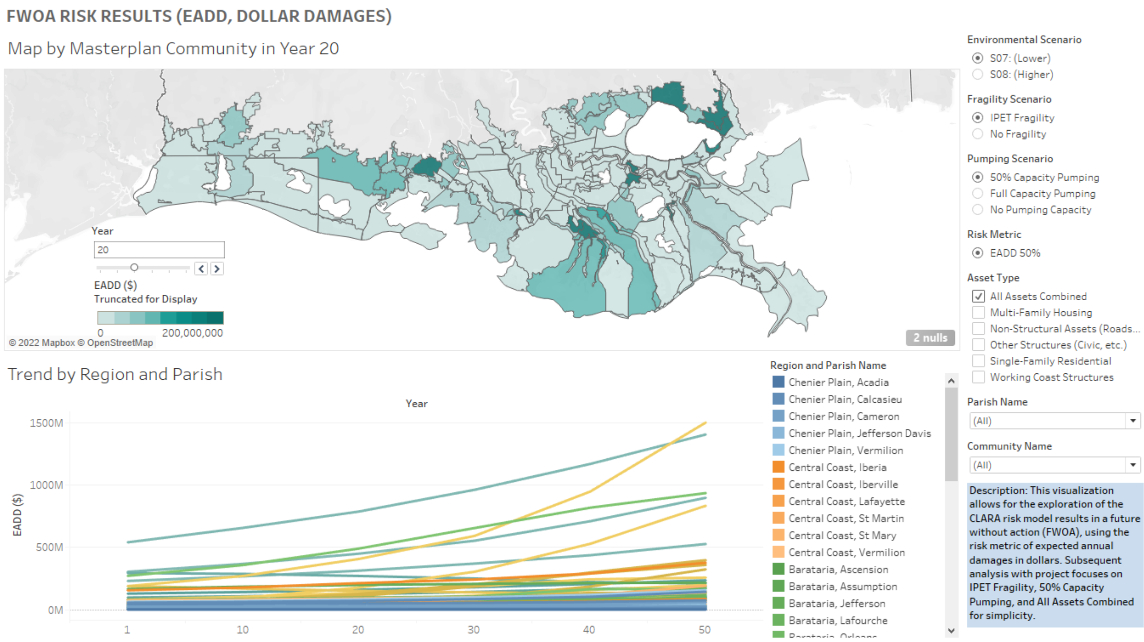


Figure 7. FWOA EADD risk metric for the lower environmental scenario, IPET fragility, 50% capacity pumping, and all assets combined in Year 20.

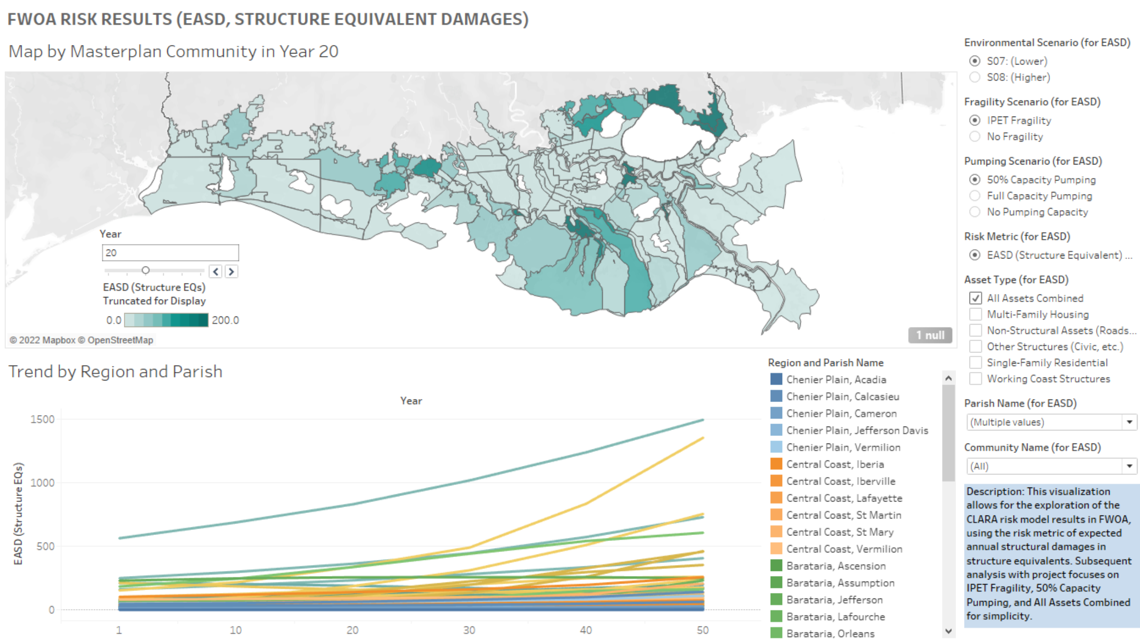


Figure 8. FWOA EASD risk metric for the lower environmental scenario, IPET fragility, 50% capacity pumping, and all assets combined in Year 20.

3.2 PROJECT ATTRIBUTE DATA

Members of the Project Development Team (PDT) compiled attribute data for each project in the PDD to support the Planning Tool analyses. Key attribute information ingested and summarized by the Planning Tool includes:

- Project basics
  - Name, location, type, etc.
- Project costs (in present dollars)
  - Planning, engineering, and design (distributed over construction period)
  - Construction (similarly distributed over time)
  - Annual operations and maintenance (annual costs)
- Project phase durations (years)
  - Engineering and design
  - Construction
- Project sediment requirements, sources, and costs

In order to model some marsh creation projects, the Planning Tool Team separated their constituent parts into elements and then arithmetically recombined them. Other projects are designed to be implemented independently. The CPRA Team developed a list of mutually exclusive projects and provided it to the Planning Tool Team, which maintained a hard-coded lookup table. For example, Table 2 shows four ridge restoration projects that are mutually exclusive with landbridge projects, as the landbridge projects include the ridge features. In addition, Table 3 shows combined marsh creation projects that are exclusive with the selection of their individual elements.

Table 2. Mutually Exclusive Ridge Restoration Projects

RIDGE RESTORATION PROJECT	CONFLICTING LANDBRIDGE PROJECTS
BAYOU POINTE AUX CHENES RIDGE RESTORATION	EASTERN TERREBONNE BASIN LANDBRIDGE - CENTRAL EASTERN TERREBONNE BASIN LANDBRIDGE - EAST
BAYOU TERRE AUX BOEUFS RIDGE RESTORATION	SOUTH BRETON BASIN LANDBRIDGE MARSH CREATION – CENTRAL SOUTH BRETON BASIN LANDBRIDGE MARSH CREATION - EAST
BAYOU AUX CHENES RIDGE RESTORATION	SOUTH BRETON BASIN LANDBRIDGE MARSH CREATION – WEST SOUTH BRETON BASIN LANDBRIDGE MARSH CREATION - CENTRAL
BAYOU L'OURS RIDGE RESTORATION	LOWER BARATARIA BASIN LANDBRIDGE LOWER BARATARIA BASIN LANDBRIDGE - WEST

Table 3. Mutually Exclusive Marsh Creation Projects

MARSH CREATION PROJECT	CONFLICTING MARSH CREATION PROJECT ELEMENTS
SOUTH BRETON LANDBRIDGE MARSH CREATION	SOUTH BRETON LANDBRIDGE MARSH CREATION - CENTRAL SOUTH BRETON LANDBRIDGE MARSH CREATION - EAST SOUTH BRETON LANDBRIDGE MARSH CREATION - WEST
LOWER BARATARIA LANDBRIDGE	LOWER BARATARIA LANDBRIDGE - WEST LOWER BARATARIA LANDBRIDGE - EAST
MID BARATARIA LANDBRIDGE	MID BARATARIA LANDBRIDGE - WEST MID BARATARIA LANDBRIDGE - EAST
EASTERN TERREBONNE LANDBRIDGE	EASTERN TERREBONNE LANDBRIDGE - WEST EASTERN TERREBONNE LANDBRIDGE - EAST EASTERN TERREBONNE LANDBRIDGE - CENTRAL

In addition, the CPRA Team determined several project exclusion decisions for IP2 based on expected effects, the need for more research, or to expedite Planning Tool analysis relative to the model runs:

- Excluded due to expected interaction IP1-selected project
  - Increase Atchafalaya Flow to Terrebonne
- Considered in IP1, but were captured by other projects selected in IP1 and replaced with an Upper Basin Diversion Program in IP2
  - Ama Sediment Diversion
  - Western Maurepas Sediment Diversion
  - Union Freshwater Diversion
  - Edgard Diversion
- Project that induced significant land loss across environmental scenarios in IP1 was excluded from consideration in IP2
  - Southwest Pass Tidal Prism Control and Acadiana Bay Hydrologic Restoration
- Project excluded from IP2 as the component was selected in IP1
  - Bayou Pointe Aux Chenes Ridge Restoration
- Component selected in IP1, and replaced with another component in IP2
  - Eastern Terrebonne Landbridge (replaced with West and Central)

There were also nonstructural investments in communities that were always mutually exclusive relative to structural risk reduction projects:

- Ascension-UNC-PO-undelimited
- Delcambre-Iberia-CC-in
- Lafitte/Jean Lafitte/Barataria-Jefferson-BA-in
- St Mary-ATD-CC-out

3.3 PROJECT DEFINITIONS

The ICM and CLARA predictive models evaluated 113 restoration and 18 structural risk reduction projects (see Figure 9), as well as two nonstructural project variants distributed across the coast.

Figure 9. Restoration and structural risk reduction projects evaluated.

RESTORATION PROJECTS

For the 2023 Coastal Master Plan, the Planning Tool evaluated 113 restoration projects, including hydrologic restoration, ridge restoration, marsh creation, diversion, and integrated projects, which incorporate distinct types of features within a single project (e.g., marsh creation and ridge restoration). Additional information on these projects is available in Supplemental Material F1.4: 2023 Coastal Master Plan Candidate Project List and Map.

In some cases, the individual projects are composed of project elements. Some project elements are prerequisites for others, and some elements represent portions of the project that the Planning Tool can independently select for each IP.

Shoreline protection, oyster barrier reefs, and barrier island projects are not included in the Planning Tool. The 2023 Coastal Master Plan considers these activity types programmatically – in other words, $2.5 billion (B) of restoration funding will be set aside in the budget. These projects typically require site-specific information for effective evaluation making it difficult to compare performance at different locations across the coast based on idealized attributes. In addition, treating them programmatically allows for flexibility in the scope and timing of their implementation.

STRUCTURAL RISK REDUCTION PROJECTS

The 2023 Coastal Master Plan evaluated 18 structural risk reduction projects across the coast:

- Abbeville and Vicinity
- Amelia Levee Improvements
- Braithwaite to White Ditch
- Fort Jackson to Venice
- Franklin and Vicinity
- Greater New Orleans High Level
- Iberia/St. Mary Upland Levee
- Lafitte Ring Levee
- Lake Pontchartrain Barrier
- Larose to Golden Meadow
- Morgan City Back Levee
- Morganza to the Gulf
- Oakville to La Reussite
- Phoenix to Bohemia Back Levee Structural Protection
- Slidell Ring Levees
- St James-Ascension Parishes Storm Surge Protection

- St. Jude to City Price
- Upper Barataria Risk Reduction

Additional information on these projects is available in Supplemental Material F1.4: 2023 Coastal Master Plan Candidate Project List and Map.

NONSTRUCTURAL RISK REDUCTION PROGRAM

This section includes an abbreviated description of the nonstructural risk reduction program for context, but for more detail on the Risk Assessment Team's selection methodology and characterization, please refer to Attachment E3: Nonstructural Risk Reduction Evaluation Results.

Nonstructural projects represent a mix of mitigation measures that would apply to numerous structures in a specific project area. For each project area, several different project variants were defined to represent distinct ways of determining how many and which structures need nonstructural risk reduction measures. Nonstructural project variants are defined by the standards for mitigation heights used to determine which structures should be elevated, floodproofed, or acquired. The standards are determined by median estimates of the 1% Annual Exceedance Probability (1% AEP or 1- in 100-year) flood depths at each CLARA model grid point under a specified landscape scenario and year plus two feet of freeboard. Each nonstructural project area then identified the number of structures and costs for elevating, floodproofing, and acquiring properties to reduce flood risk:

- **Elevation of residential structures:** Recommended in areas where the mitigation standard is greater than 3 ft but less than the elevation for voluntary acquisition (described below)
- **Floodproofing of multi-family and non-residential structures**: Recommended in areas where the mitigation standard is less than 3 ft
- **Voluntary acquisition for residential structures**: Recommended in areas where the mitigation standard is greater than a pre-specified threshold (the variants used in the Planning Tool utilized 14 ft)

The Risk Assessment Team did not consider grid point locations with no 1% AEP flood depths as investment candidates. In consultation with CPRA and the Risk Assessment Team, two variants were considered in Planning Tool analysis, one for IP1 that used the lower environmental scenario and 1% AEP flood depth target in Year 0 with an acquisition threshold of 14 ft, and one for IP2 that used the lower environmental scenario and 1% AEP flood depth target in Year 30 with an acquisition threshold of 14 ft.

Whereas the 2017 Coastal Master Plan selected specific communities for nonstructural implementation, the 2023 Planning Tool selected an overall programmatic budget of nonstructural projects consistent with a certain amount of risk reduction, but not necessarily located in a specific location. First, the Planning Tool compared the benefits of identified nonstructural projects by community to those of structural protection projects. This analysis supported the Planning Tool's selection of structural risk reduction projects. Within a community structural and nonstructural projects are considered mutually exclusive. For example, if the Planning Tool selects nonstructural rather than structural protection for a community, the structural project may not be considered for selection. Subsequently, the Planning Tool aggregated the associated costs of the nonstructural projects across the coast to define an appropriate level of investment. This level of funding reduced the amount of funding available for structural projects.

3.4 SEDIMENT REQUIREMENTS

For the 2017 Coastal Master Plan, the Planning Tool tracked sediment borrow source requirements for specific projects and allocated the borrow from individually defined sources to those projects requiring sediment. Each predetermined project cost was based on a single fixed borrow source that once depleted behaved as a constraint. For 2023, the team reconfigured the Planning Tool to allow an individual project or project element to obtain borrow from more than one source, if cost efficient to do so, and to track the cost of using the single or selected combination of borrow sources. This removed sediment as a constraint. To implement this, the Planning Tool Team requested several changes to the project attribute data available in the PDD:

- **Separate borrow costs from other construction costs:** The Construction Cost project attribute excludes the cost of the borrow
- **A project element/borrow cost matrix**: This matrix specifies for each project element requiring borrow the per volume cost of obtaining borrow from each of the possible sources. There is also a fixed cost for borrow use independent of volume. For coding purposes, a single matrix lists for each project the plausible sediment sources by element
- **Constituent elements for marsh creation and other projects:** The 2023 Planning Tool allows the required borrow for each project element to be met by different sources while maximizing land, subject to the budget and borrow constraints. In practice this means including the per volume borrow costs and the borrow requirements for each project element in the Planning Tool cost constraint

For the 2023 Coastal Master Plan, CPRA identified 41 individual sediment sources (see Figure 10 for locations and Supplemental Material F1.5: 2023 Available Sediment by Borrow Source for more detail). For sources that are not within the Mississippi River channel, the PDD specifies a single amount of sediment that can be drawn upon until exhausted. The PDD, in contrast, considers Mississippi River-based sources to be renewable. CPRA assigned these sources a ten-year renewable fill volume available at any time in those ten years, preventing the sediment – twice the fill volume – from being used all at once. The Planning Tool imported both types of sediment sources in a simple table containing the amount of sediment available for each IP and parameters specifying how the sediment source can be replenished. For example, assuming the demand for sediment is 100 units for Project X in IP1 and the replenishment rate is 10 years with a fill volume of 50, the Planning Tool forces the project to pull sediment in across two decades, Years 0 to 10, and Years 11 to 20 (if more cost-effective than an alternative source). As an important note, the Planning Tool Team used an approximation so that that the sediment removal time does not feed back into the PDD to increase the project completion time.

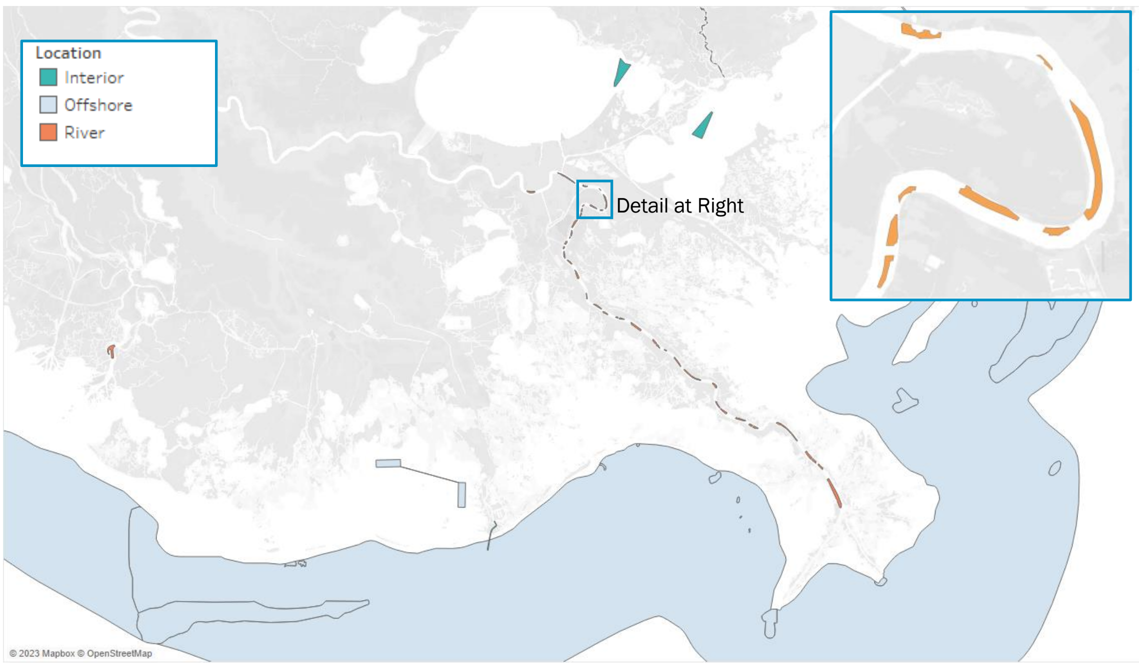


Figure 10. Zoomed in map of a sample of sediment borrow sources for context.

3.5 PROJECT COST CALCULATIONS

The Planning Tool distributes each project's engineering, design, and construction costs and sediment requirements over time to determine how much applies to each IP. It then applies the annual operations and maintenance cost to each year after construction is complete. Table 4 provides an example for the Pointe a la Hache and Carlisle Marsh Creation's costs and duration for each phase if implemented in IP1. A project may have several marsh elements that can be picked independently, and several borrow sources can provide sediment to this element and the cost and available sediment volume varies. The cost increase of the higher scenario is caused by the need for two borrow sources and thereby higher fixed cost.

Table 4. Example Pointe a la Hache and Carlisle Marsh Creation Project Costs and Durations in IP1

	COSTS LOWER SCENARIO	COSTS HIGHER SCENARIO	DURATION
ENGINEERING AND DESIGN	$13.6M	$16,2M	3 YEARS
CONSTRUCTION	$171M	$200M	5 YEARS
OPERATIONS AND MAINTENANCE	$5,7M	$6.7M	UNTIL YEAR 50

Project costs have a large range depending on their size and type and may vary widely depending on requirements for sediment sources. For example, an integrated project, Lower Plaquemines River Sediment Plan (ID: 3270000), has the most expensive minimum cost in the lower environmental scenario of $2,569M, with potentially up to $131M in additional sediment costs depending on borrow sources. The graphics displayed in the Tableau workbook reflect the average implemented sediment costs and the mid-level cost scenario, though the alternative optimization routine draws upon the actual implemented sediment costs for its project selection (see Figure 11).

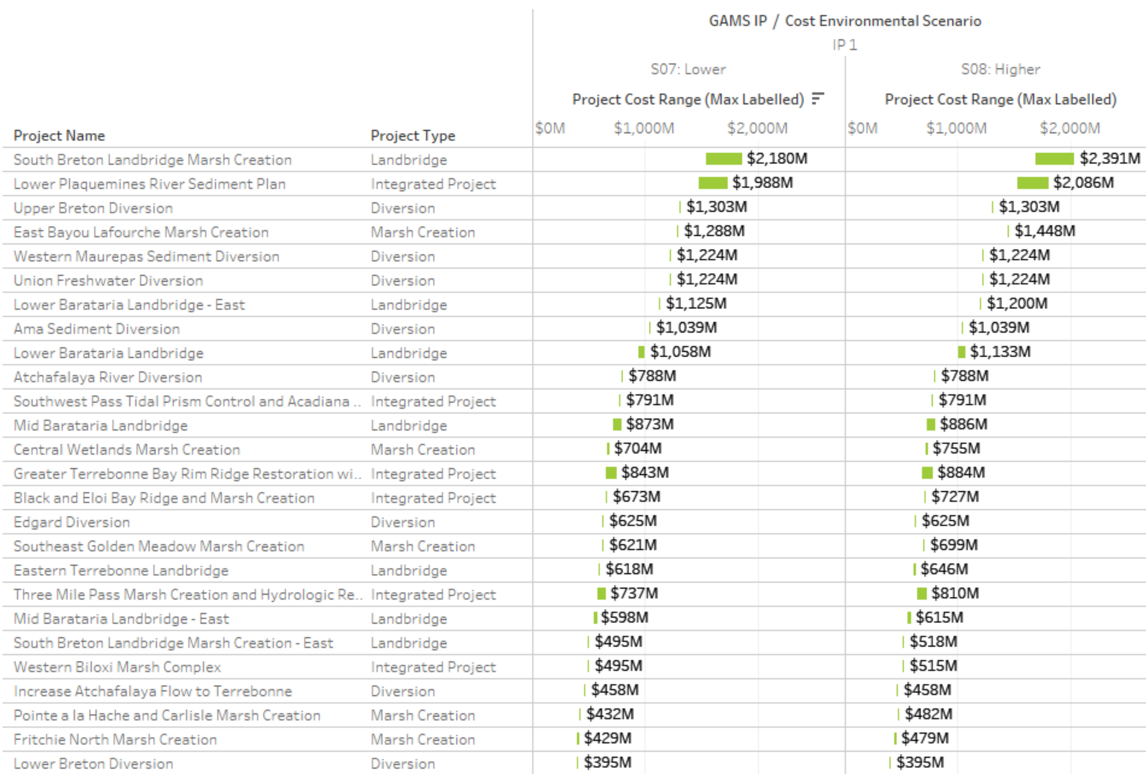


Figure 11. Selected restoration project costs in descending order for IP1.

SINGLE MODELING STEP SELECTION MODE

How the Planning Tool selects projects determines how it calculates costs for the two IPs. The Planning Tool can operate in two modes. The first – *Single Modeling Step Selection* – uses just one model input. This is the method used for risk reduction projects. In IP1, projects are selected on their effect relative to FWOA conditions for a given budget. Projects not selected in IP1 are then available for selection in IP2.The Planning Tool then transposes the benefits in time from IP1 to IP2. Therefore, a risk reduction project in IP2 has zero effect for the first 20 years. Engineering, design, and construction costs are then incurred beginning in IP2, with effects interpolated over the construction period. This process is implemented in the Planning Tool by using an offset project cost and effect matrix (see Figure 12 for an illustrative example of how these benefits and costs are distributed annually depending on the period of implementation).

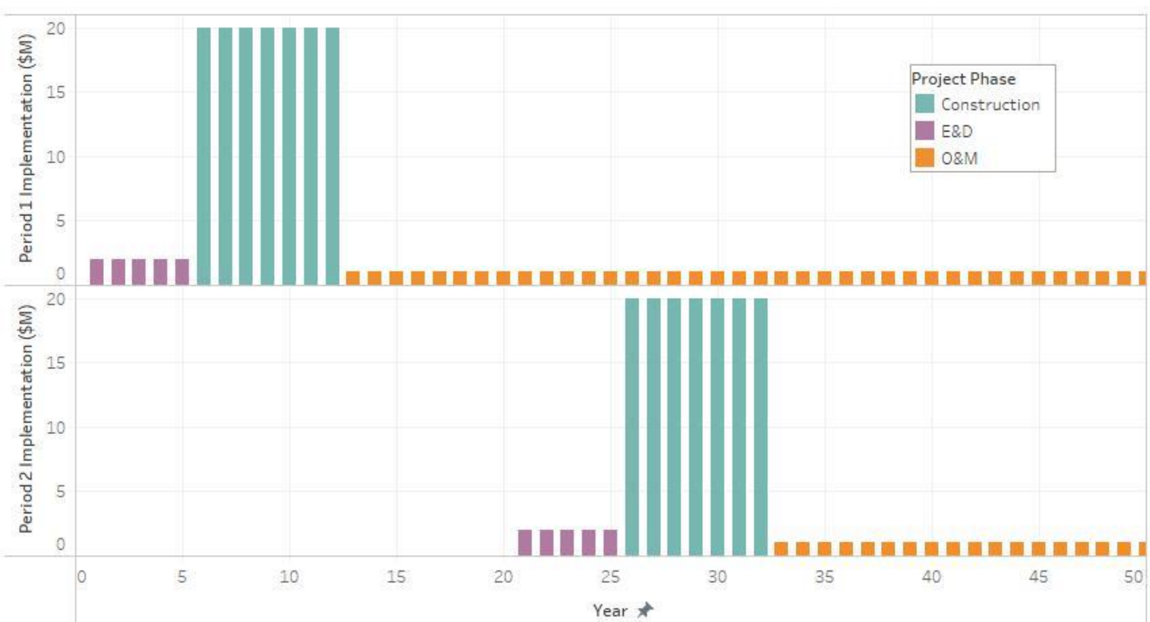


Figure 12. Comparison of hypothetical project cost distribution for two IPs.

ITERATIVE MODELING STEPS SELECTION MODE

The second mode – *Iterative Modeling Steps and Selection* mode – includes an additional modeling step in which restoration projects selected for implementation in IP1 are modeled on the landscape to create a revised 'no action' condition (Future with IP1 – FWIP1). This then forms the basis for modeling the effects of restoration projects being evaluated for selection in IP2. Instead of transposing benefits and assuming that benefits in later years are the same as benefits in earlier years if the project is started later, this approach provides a better estimate of the dynamic and combined effects of projects when implemented in IP2. The remodeled projects mean that IP2 benefits are calculated against the FWIP1 baseline over the thirty years of project performance in IP2, and change the project costs (especially given different sediment borrow requirements and source availability, as seen in Figure 13 as compared to Figure 11).

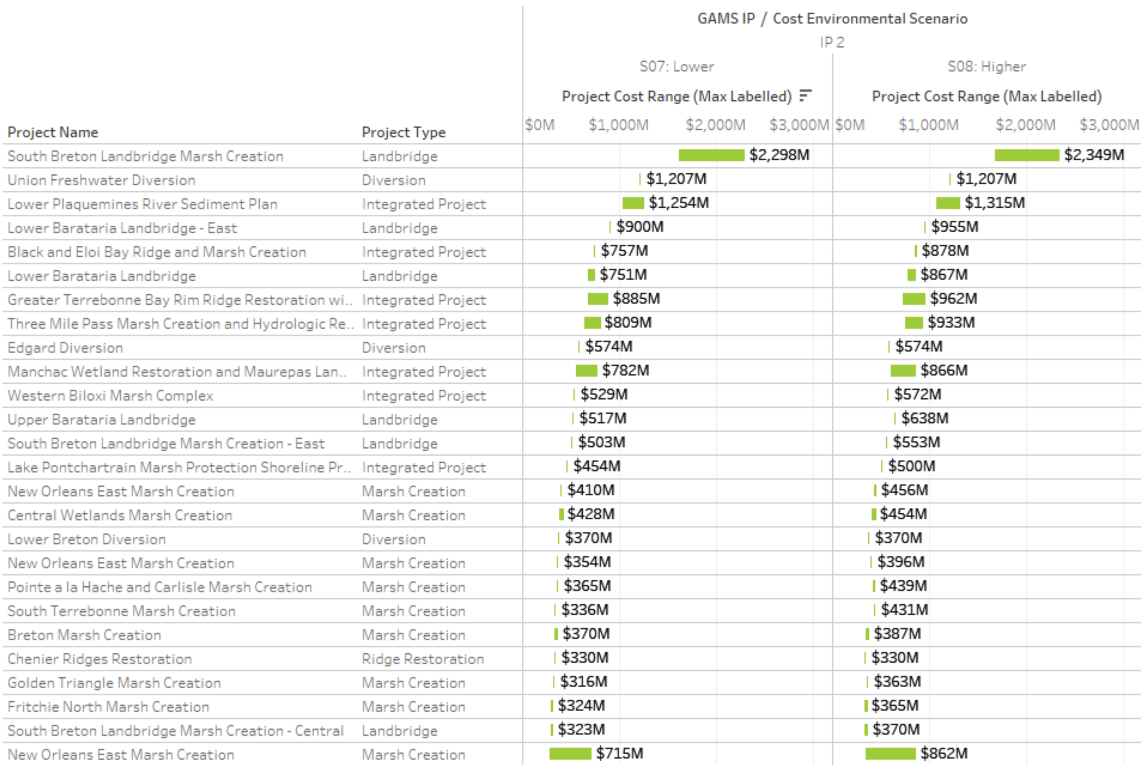


Figure 13. Selected restoration project costs in descending order for IP2.

3.6 PROJECT BENEFIT CALCULATIONS

The team has access via the PDD to FWOA risk data for every ten years starting in Year 10. Benefit data of the risk projects was available starting in Year 20 with the same interval. Conditions at the onset of the projects, initial conditions, were known and used to interpolate future without action data from start to Year 10. We used linear interpolation at each interval to gain yearly data. We assumed that structural projects provide some benefit as they are being constructed, for example from floodgates or early levee lifts before the project reaches its final elevation. The team decided to assign a fractional benefit from the construction half-point to the project's completion. By comparing the benefit to the FWOA value at Year 20 and reducing the benefits by 25%, we could use the yearly FWOA values to estimate the benefits during construction. Similarly, we estimated the benefit from construction to Year 20 by utilizing the fraction, but without reducing the benefit.

When modeling the restoration projects, we received yearly data for benefits based on the completion of construction. To represent the potential for land benefits during the construction period, e.g., as a marsh creation area is gradually filled, benefits were linearly interpolated between the start and end of the construction period.

4.0 COMPARING PROJECTS

The Planning Tool performs a variety of functions in support of the CPRA master plan development, as listed and summarized in Figure 14. This section details the comparison of projects, whereas Section 5.0 formulates alternatives, Section 6.0 evaluates alternatives, and Section 7.0 supports deliberations upon the delivery of the 2023 Coastal Master Plan.

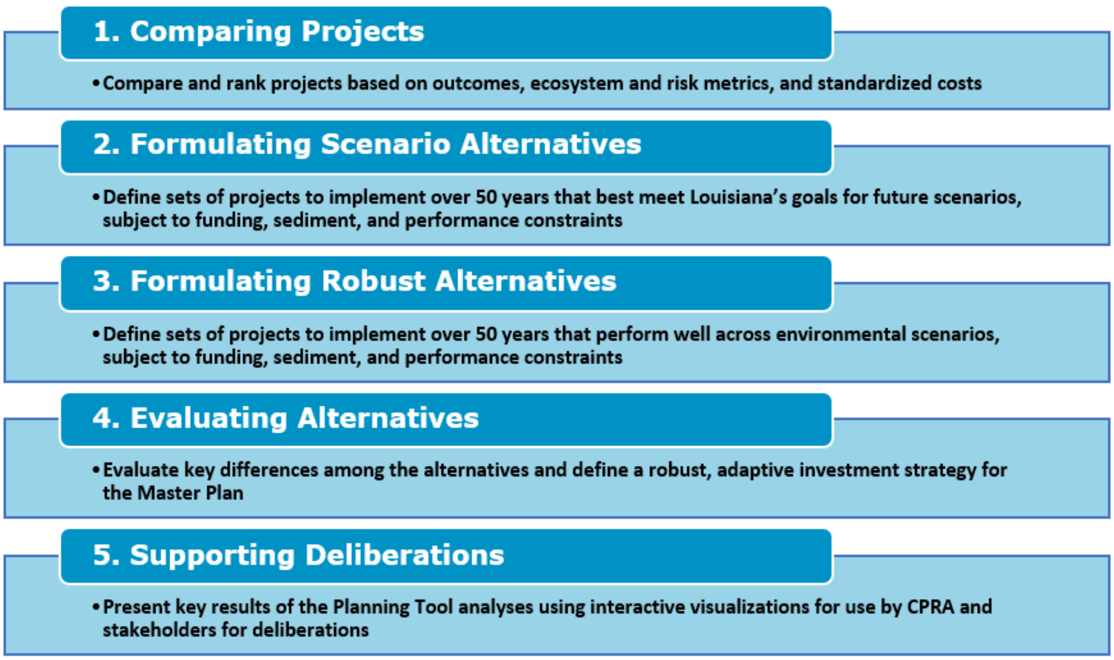
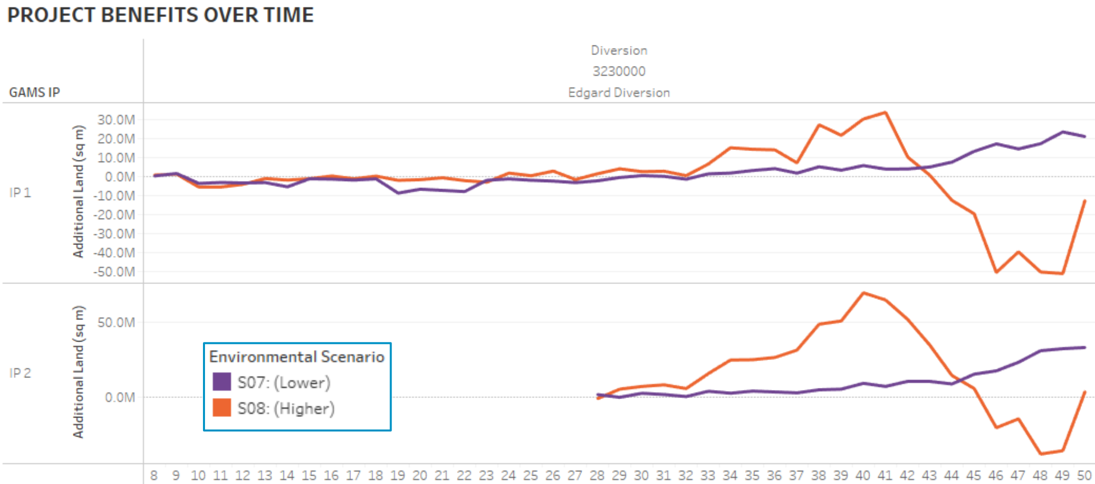


Figure 14. Outline of key Planning Tool functions.

4.1 PROJECT EFFECTS

RESTORATION PROJECTS

The predictive models estimate the individual effects of each project for all project-specific metrics and environmental scenarios. This calculation is based on the difference between the future with action and the FWOA condition. This information is initially provided assuming that each project would be implemented in Year 1. For projects not selected in the first IP, the predictive models then estimate the project effects if they were to be implemented in Year 21. Net project benefits (which includes both prevention of loss as well as land building) vary over time, with some having steady trends whereas others may reverse directions or have dramatic systemic feedback mechanisms. Tables report out AAL over the five decades and Year 50 total land, the former of which is used for alternative selection. Note that different environmental scenario assumptions may yield substantially different outcomes (including positive vs. negative benefits). These benefits are also broken out by ecoregion to understand where and how there may be differential effects across the coast. For example, in Figure 15, the Edgard Diversion (ID: 3230000), implemented in IP1, in the lower environmental scenario relative to FWOA spends most of the 50-year period building a moderate amount of land, ending with a net of 20.9 million square meters of land. In the higher environmental scenario, it largely tracks the lower environmental scenario through approximately Year 30, when it exceeds FWOA land. It then decreases land relative to FWOA, and after staging a brief recovery in the last few years, still ends in negative territory relative to FWOA (-12.7 million square meters). As the lower set of plots reveals, the dynamic is somewhat similar, but more exaggerated on an annualized basis if the project is selected in IP2, showing the importance of not only the *Iterative Modeling and Selection* mode, but also AAL as the Planning Tool's decision driver. In IP1, the project would be a candidate for selection only if being optimized for the lower environmental scenario, and perhaps in the robust alternative depending on other available projects. In contrast, the project is likely a strong candidate for selection in IP2 in either environmental scenario as well as the robust alternative.



Sortable Project List of Average Annual Land and Year 50 Land

			GAMS IP / Environmental Scenario							
			Avg. Annual Land				Year 50 Total Land			
			IP 1		IP 2		IP 1		IP 2	
Project ID	Project Name	Project Type	S07: (Lower)	S08: (Higher)	S07: (Lower)	S08: (Higher)	S07: (Lower)	S08: (Higher)	S07: (Lower)	S08: (Higher)
2430000	Ama Sediment Diversion	Diversion	-30.76M	-112.18M			-44.08M	-381.17M		
1080000	Atchafalaya River Diversi..	Diversion	24.98M	23.99M			32.55M	64.98M		
140000	Central Wetlands Diversi..	Diversion	4.81M	11.25M	7.67M	10.89M	25.53M	52.37M	17.97M	31.53M
3410000	Charenton Diversion	Diversion	-0.85M	-9.48M	1.29M	4.11M	3.83M	-51.85M	8.30M	6.88M
3230000	Edgard Diversion	Diversion	1.64M	-1.43M	7.66M	12.71M	20.93M	-12.68M	32.91M	3.53M
3220000	Freshwater Delivery to W..	Diversion	-1.60M	-2.68M	18.79M	15.67M	-2.81M	-8.64M	26.29M	28.14M
1390000	Increase Atchafalaya Flo..	Diversion	11.16M	-31.53M			11.65M	-168.24M		

Figure 15. Selected project effects for Edgard Diversion showing land building trends over time by IP as well as environmental scenario.

An annual understanding of project dynamics relative to FWOA is helpful for stakeholder understanding, but it is also a useful reminder that the Planning Tool only looks at net project benefits. Figure 16 explores how some projects have the same direction of AAL effects in both environmental scenarios and/or IPs, whereas others like the Edgard Diversion are dependent on time and context.

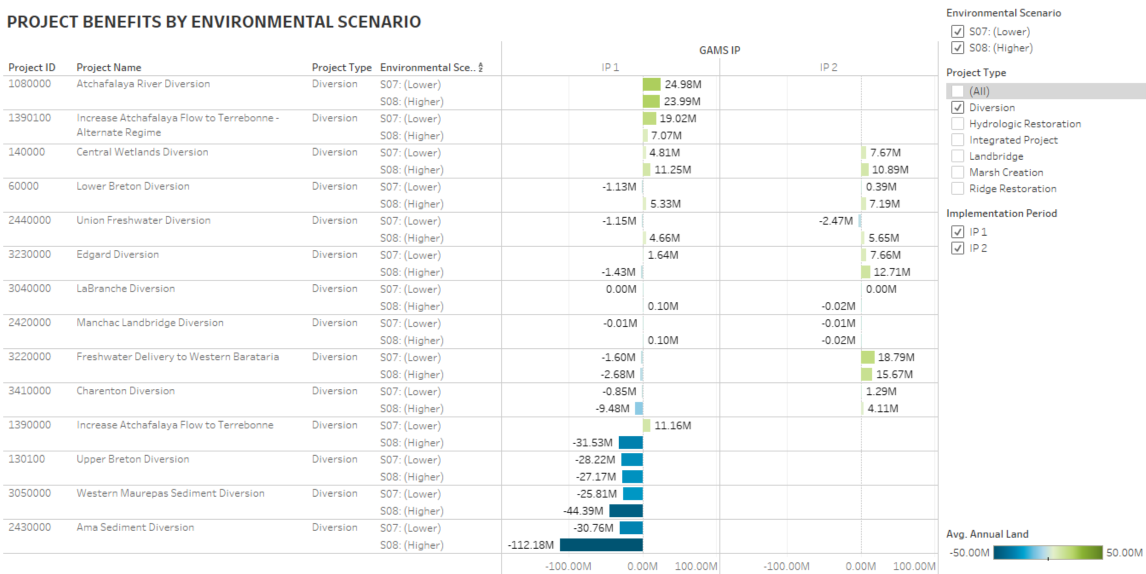


Figure 16. AAL effects for diversion projects by IP and environmental scenario.

While the above values reflect coastwide decision drivers for project selection in the Planning Tool, another important aspect of project performance for stakeholders are the relative regional benefits. This is one of the many ways that the Planning Tool can support iterative deliberations with the CPRA Team and inform whether the Planning Tool Team may need to explore additional outcome constraints. For example, we see in Figure 17 that with the Edgard Diversion in IP1 under the lower environmental scenario, the 1.91 million square meters of AAL benefits are not evenly distributed by region, with Terrebonne gaining 0.9 million square meters AAL compared to Barataria adding 0.1 million square meters AAL. In contrast, the Pontchartrain/Breton region is losing 0.3 million square meters AAL. Decision-makers and stakeholders may find these to be key considerations, especially as the same project on the future with project landscape in IP2 results in stronger gains for all regions.

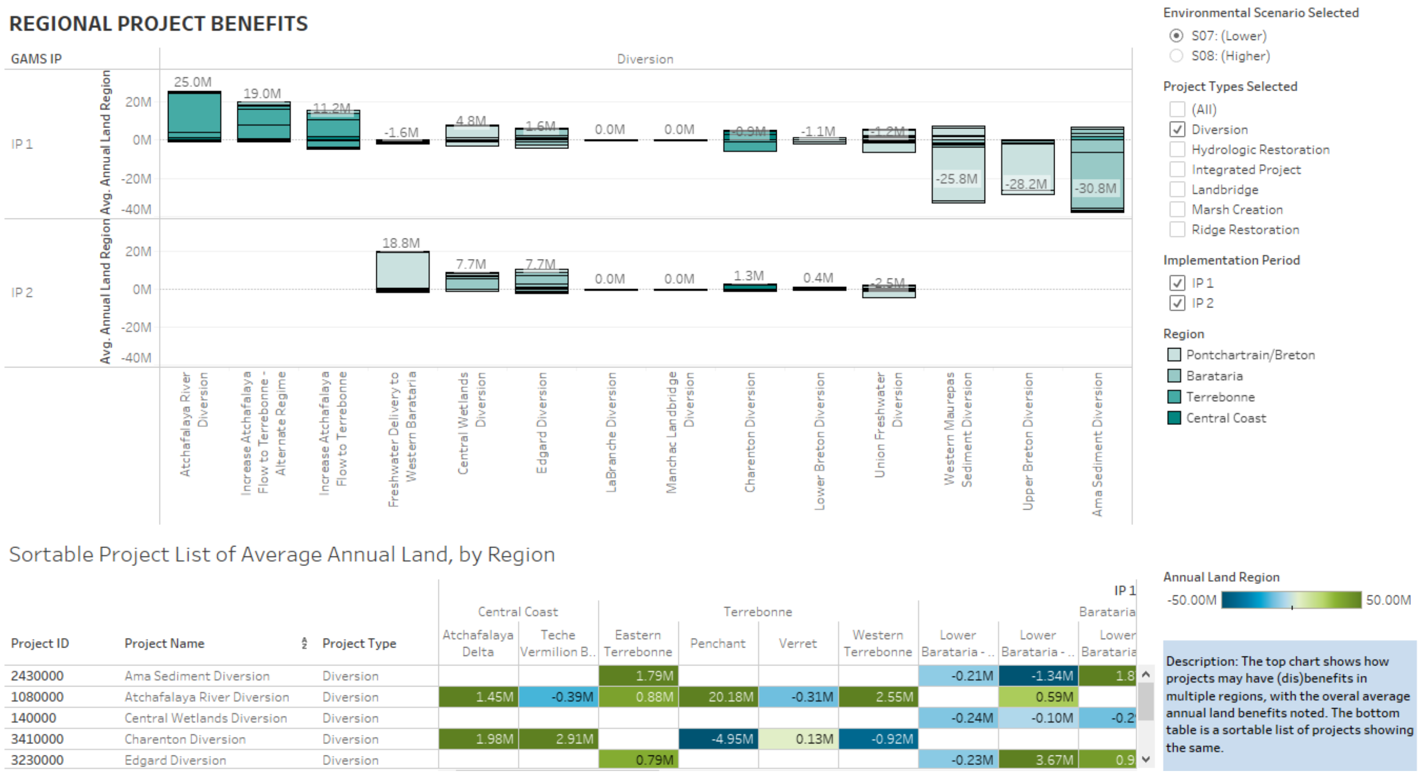


Figure 17. Sample of regional project benefits for diversions under the lower environmental scenario for IP1 and IP2.

RISK REDUCTION PROJECTS

The Planning Tool's exploration of risk projects follows a similar format to that of the restoration projects, except with the key difference of there being a dual objective function of EADD and EASD. There are other, smaller differences, such as a lower temporal resolution (using interpolated data) and less variability in the benefits curves over time than in restoration projects. In contrast, there is a higher level of geographic granularity to master plan communities. Similar to restoration, there is the potential for negative project effects, due to induced flooding in communities outside of levee protection. Figure 18 shows an example of this display in the Planning Tool for the Morganza to the Gulf Structural Risk Reduction project.

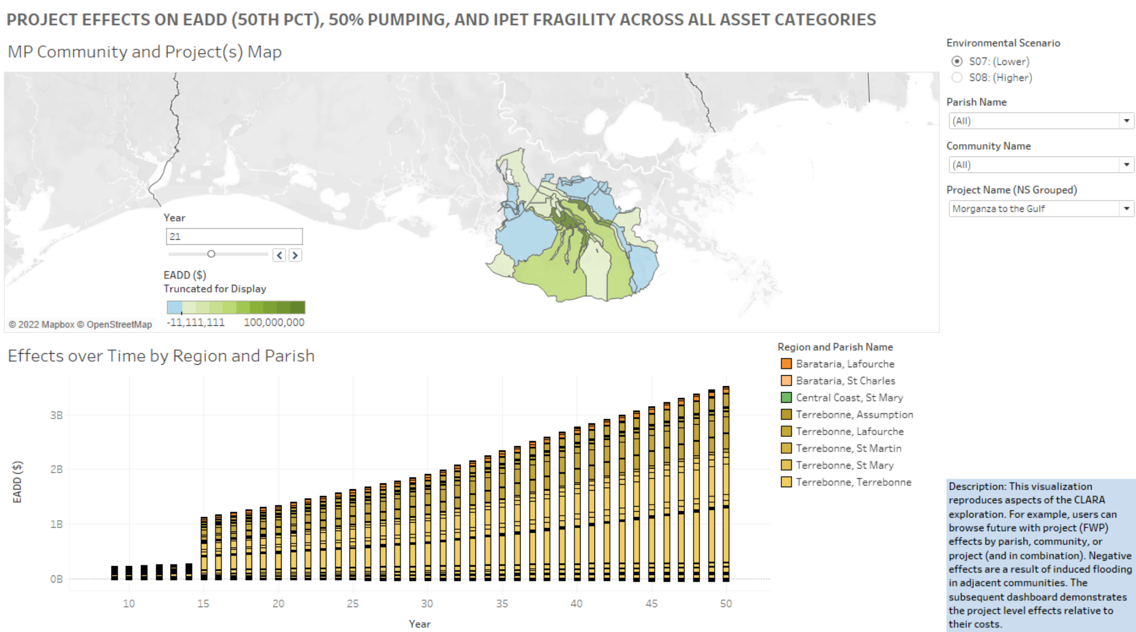


Figure 18. Morganza to the Gulf Structural Risk Reduction project in IP1 showing geographic effects in Year 21 to impacted communities, as well as effects over time by region and parish for the lower environmental scenario.

4.2 COST-EFFECTIVENESS

The Planning Tool compares individual projects based on predictive model estimates of their effects on the coast and the effects scaled by total project cost. Rankings of projects by outcomes and cost-effectiveness for key metrics provide CPRA and stakeholders with a first-order assessment of which projects could most efficiently help achieve Louisiana's goals. To calculate the cost-effectiveness, the Planning Tool takes the project's AAL (whether over both IP1 and IP2, or IP2 alone) and divides that value by the planning, design, and construction costs, as well as operations and maintenance costs from implementation through the 50-year time horizon.[4] The cost-effectiveness therefore varies by both environmental scenario and IP. Figure 19 and Figure 20 show a sample of these calculations for diversion restoration projects in both environmental scenarios and IPs. For example, the Edgard Diversion in IP1 under the lower environmental scenario has a relatively low, but at least positive cost-effectiveness of approximately 3,000 square meters of AAL per $1 million investment. In contrast, in IP2 it would have a higher cost-effectiveness of 17,400 square meters of AAL per $1 million or 28,900 square meters of AAL per $1 million under the lower and higher environmental scenarios, respectively, although that may still not be high enough for selection depending on available budget for a given alternative.

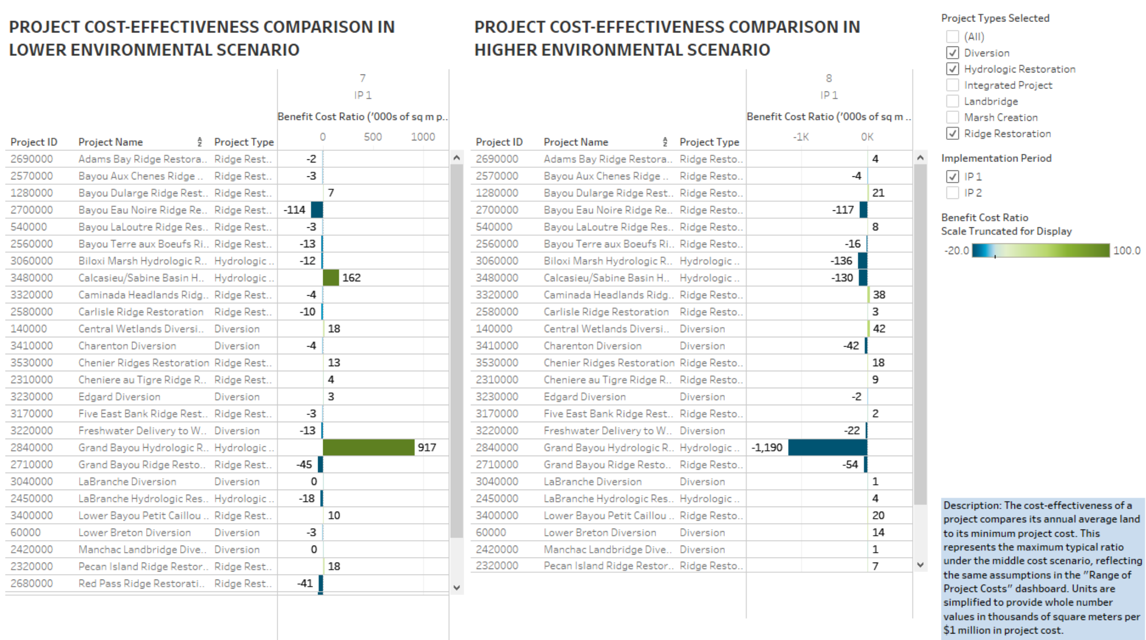


Figure 19. Project cost-effectiveness comparison for diversion, hydrologic restoration, and ridge restoration projects across environmental scenarios for IP1.

4 The Planning Tool Team uses the general concept of cost-effectiveness throughout this report, as unlike the term benefit-cost ratio, it does not require the numerator to be in the same units as the denominator (dollars). Cost-effectiveness therefore can have AAL or EASD as the numerator in comparison to EADD alone.

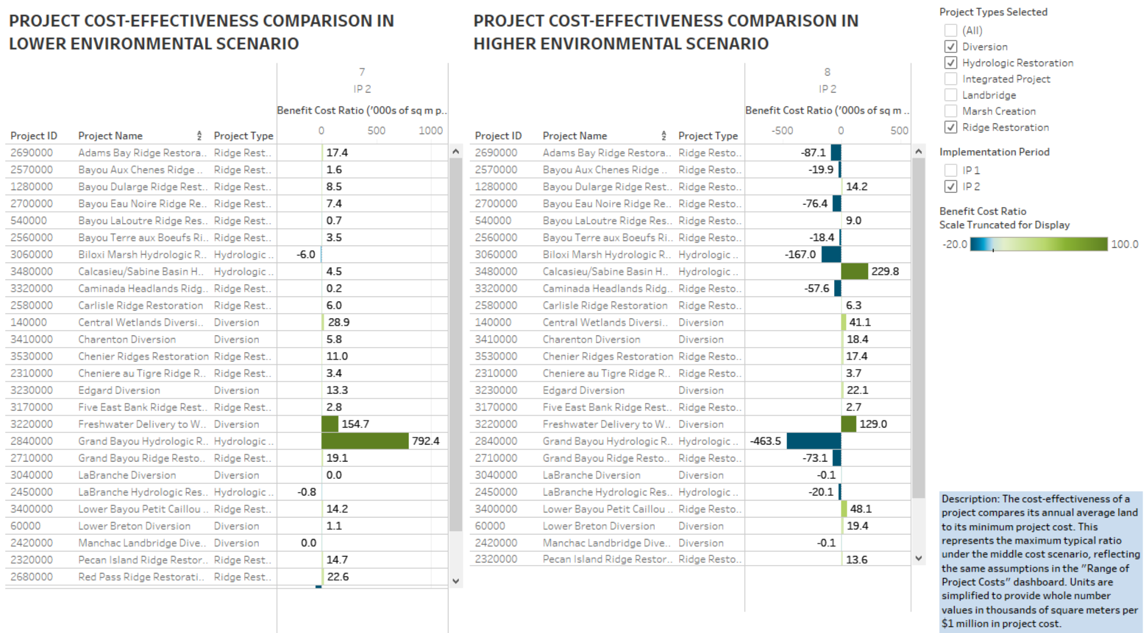


Figure 20. Project cost-effectiveness comparison for diversion, hydrologic restoration, and ridge restoration projects across environmental scenarios for IP2.

ANNUALIZED BENEFIT COST RATIOS FOR STRUCTURAL AND NONSTRUCTURAL RISK PROJECTS

EADD as Risk Metric

Project ID	Project Name	Total Cost over 50 Years	Cumulative EADD in S07	Cumulative EADD in S08	Ann. BCR EADD S07	Ann. BCR EADD S08
2920000	Abbeville and Vicinity	$626,031,263	$3,863,773,101	$5,133,259,591	0.123	0.164
1440000	Amelia Levee Improvements	$857,120,065	$805,126,713	$1,919,731,962	0.019	0.045
3190000	Braithwaite to White Ditch	$440,173,378	$3,060,569,573	$3,680,064,884	0.139	0.167
2640000	Fort Jackson to Venice	$68,448,792	$232,529	$8,468,486	0.000	0.002
1480000	Franklin and Vicinity	$316,431,092	$2,637,926,867	$3,786,113,189	0.167	0.239
260000	Greater New Orleans High Level	$3,176,045,395	$773,634,082	$2,824,551,029	0.005	0.018
1500000	Iberia/St. Mary Upland Levee	$1,717,849,075	$15,379,097,894	$19,526,971,350	0.179	0.227
830000	Lafitte Ring Levee	$1,386,384,339	$9,345,160,890	$10,566,484,485	0.135	0.152
290000	Lake Pontchartrain Barrier	$2,383,550,181	$28,613,074,621	$30,702,725,764	0.240	0.258
1110000	Larose to Golden Meadow	$500,572,810	$244,159,446	$645,386,739	0.010	0.026
1460000	Morgan City Back Levee	$114,887,484	($22,102,056)	$74,521,574	-0.004	0.013
1100100	Morganza to the Gulf	$3,933,007,097	$93,887,094,187	$127,000,000,000	0.477	0.646

EASD as Risk Metric

Project ID	Project Name	Total Cost over 50 Years	Cumulative EASD in S07	Cumulative EASD in S08	Ann. BCR EASD S07 (per $M)	Ann. BCR EASD S08 (per $M)
2920000	Abbeville and Vicinity	$626,031,263	4,412.18	5,933.09	0.141	0.190
1440000	Amelia Levee Improvements	$857,120,065	468.12	1,375.13	0.011	0.032
3190000	Braithwaite to White Ditch	$440,173,378	1,886.37	2,271.09	0.086	0.103
2640000	Fort Jackson to Venice	$68,448,792	0.54	5.74	0.000	0.002
1480000	Franklin and Vicinity	$316,431,092	2,205.07	3,191.23	0.139	0.202
260000	Greater New Orleans High Level	$3,176,045,395	456.80	1,661.43	0.003	0.010
1500000	Iberia/St. Mary Upland Levee	$1,717,849,075	11,963.23	15,443.06	0.139	0.180
830000	Lafitte Ring Levee	$1,386,384,339	11,509.96	13,054.01	0.166	0.188
290000	Lake Pontchartrain Barrier	$2,383,550,181	25,230.46	27,469.59	0.212	0.230
1110000	Larose to Golden Meadow	$500,572,810	183.82	571.55	0.007	0.023
1460000	Morgan City Back Levee	$114,887,484	-17.35	38.35	-0.003	0.007
1100100	Morganza to the Gulf	$3,933,007,097	93,221.59	123,415.67	0.474	0.628

Figure 21. Annualized benefit-costs ratios for structural risk projects by EADD and EASD risk metrics.

Structural risk reduction projects follow a similar logic, with the cost-effectiveness as either EADD or EASD per $1 million. **Error! Reference source not found.** shows these results for a selection of the projects in tabular format. For example, Morganza to the Gulf in IP1 under the lower environmental scenario reduces EADD by approximately $477,000 per $1 million investment, or $646,000 per $1 million investment if under the higher environmental scenario. Nevertheless, the Morganza to the Gulf project would benefit 0.474 structure equivalents per $1 million under the lower environmental scenario versus 0.646 structure equivalents per $1 million under the higher environmental scenario.

5.0 FORUMULATING ALTERNATIVES

The Planning Tool develops alternatives — defined as sets of selected projects to implement in each of the two IPs — that best achieve CPRA goals, subject to various constraints under environmental scenarios and other uncertainties. There is no "correct" alternative, and the Planning Tool is designed to formulate many alternatives and summarize the key differences among them. Some alternatives vary key parameters such as overall funding, whereas others consider performance with respect to other metrics, such as long-term land sustainability. The Planning Tool is flexible and can be modified to explore and evaluate options in response to CPRA and stakeholders' interests. Section 10.0 has a table of alternatives tested alongside their attributes.

5.1 OVERVIEW

In general, the Planning Tool uses an optimization model to select the restoration and risk reduction projects that will maximize land building and risk reduction. For both restoration and risk reduction projects, the procedure first selects projects to implement in IP1 (Years 1-20). The Planning Tool assumes that these projects are implemented beginning in Year 1 and that cost and sediment requirements for the first 20 years of each project must be met by IP1 funding and sediment sources. For some projects, construction costs and sediment requirements extend beyond the first 20 years. In this case, the Planning Tool ensures that sufficient budget and sediment are available in IP2. When projects are selected for IP2, the requirements for the projects selected in IP1 must be satisfied first.

The Planning Tool next selects projects to implement in IP2 (Years 21-50). Any project not selected in the IP1 is a candidate for selection (unless exempted by CPRA, as described in Section 3.2). These projects are assumed to begin engineering and design in Year 21 and accrue costs from that year forward. The Planning Tool again ensures that all funding and sediment requirements are met. As described in Section 3.5 in detail, due to data and time constraints associated with the 2023 Coastal Master Plan process, IP2 risk alternatives used the *Single Selection Step* mode, whereas *Iterative Modeling and Selection* was used for IP2 restoration alternatives.[5]

For both risk reduction and restoration alternatives, other performance constraints can also be imposed when formulating alternatives. These constraints can help 1) to better understand whether

[5] Therefore, the Planning Tool's project effects curves for EADD and EASD were not re-represented from IP1, but cost-effectiveness was adjusted and shown in dashboards to reflect the internal Planning Tool calculations.

improvements in other metrics could be achieved at a minimal effect to the decision drivers, land and EADD/EASD reduction, and 2) to ensure that specific outcomes are achieved, e.g., outcomes that are consistent with the master plan objectives, while maximizing land area and EADD and/or EASD reduction. Iterative alternative formulation and review of these results support CPRA deliberations.

5.2 OPTIMIZATION CALCULATION

The Planning Tool uses GAMS to solve a mixed integer program in which the decision variables are binary choices, *I,* to implement or not implement a project in one of the two IPs. GAMS runs the risk and restoration optimizations separately for greater accuracy. The objective is a simple function for either AAL or EADD and EASD reduction where project benefits are added together and no interaction is assumed. The algorithm maximizes the objective function subject to available funding and sediment, and some additional constraints defined below:[6]

$$Max \ \sum_{p_r}\left[\left(\sum_{y}\left(W_{EADD} \times EADD\_reduction^{*}_{y,p_r}\right) + W_{EASD} \times EASD\_reduction^{*}_{y,p_r}\right) \times I_{p_r}\right]$$

$$+ \ \sum_{p_e}\left[-\left(\sum_{y} Land\_building^{*}_{y,p_r}\right) \times I_{p_e}\right]$$

where W_{EADD} and W_{EASD} are the percentage weight of EADD versus EASD respectively (i.e. 1- W_{EADD} = W_{EASD}), y = year; r = region; p_r = selected risk projects from the alternative, p_e = selected restoration projects from the alternative and I_{pr} = {1 or 0} and I_{pe} = {1 or 0} subject to the following funding constraints:

$$\left(\sum_{p_r} I_{p_r} \times Cost_{p_r}\right) \leq RiskFunding$$

[6] Note, for risk projects, there is a theoretical-maximum for EADD and EASD reduction that could be achieved in each risk region – zero risk. Therefore, the function above limits the total EADD or EASD reduction for a region to the FWOA level of risk, as indicated by the "*". It is the case for risk reduction projects that some may be able to exceed the amount of FWOA damage if there are induced damages due to other projects. Similarly, for restoration projects we tested, but did not impose a binding constraint on land sustainability in later years, as discussed in Section 5.4.

$$\left(\sum_{p_e} I_{i,p_e} \times Cost_{p_e}\right) \leq RestorationFunding$$

and sediment constraints (for restoration projects), for each sediment source, s:

$$\left(\sum_{p_e} I_{P_e} \times SedimentRequirement_{p_e,s}\right) \leq SedimentSource_s$$

The highest value of the index is not shown above the $\sum$ as the total number of projects varies by alternative and time. The Planning Tool includes project-based constraints detailed in Sections 3.2 to ensure that it can only select one of a set of mutually exclusive projects. To calculate AAL for restoration projects, the Planning Tool simply divides IP1 projects (and their added effects in alternatives) by the full 50 years, and IP2 projects (and alternatives, similarly) by the remaining 30 years.

5.3 BUDGET CONSTRAINT

The Planning Tool considers two types of constraints – implementation constraints and outcome constraints. Implementation constraints are related to factors that limit how many or which projects the Planning Tool can select, such as available funding.

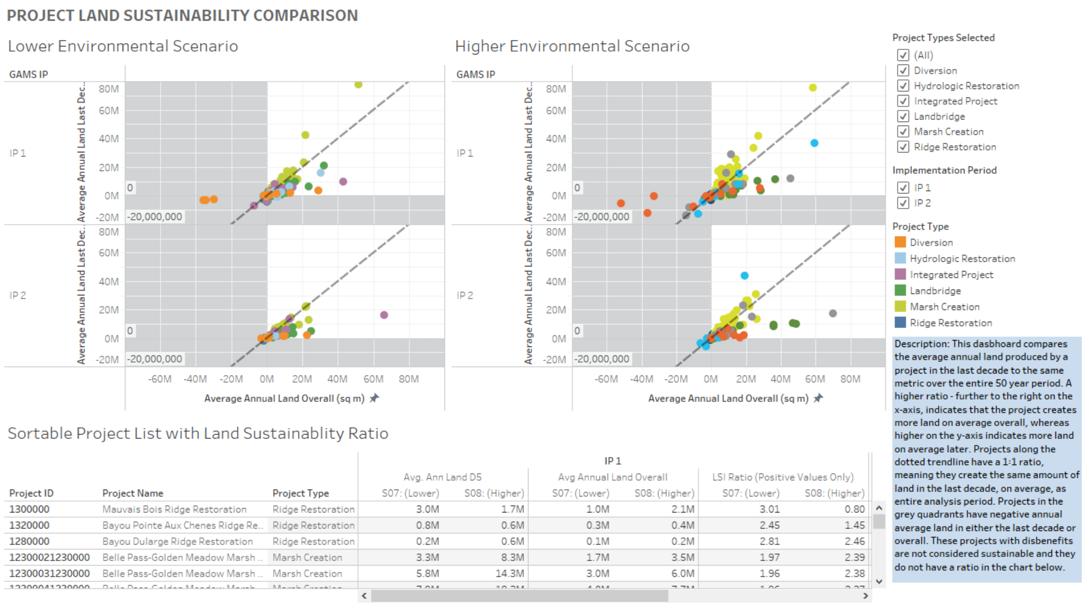
The Planning Tool Team evaluated a range of budgets for IP1 restoration projects from \$7.5B to \$15B, including \$10B, \$12B, \$12.5B, \$12.875B, \$13B, \$13.5B, \$14B, and \$14.5B. The higher budgets were set by overall master plan considerations, whereas others were used to test the sensitivity of the optimization with different amounts set aside for programmatic projects. Based on prior master plans and internal initial analysis, CPRA used \$12.5B as the anchor point (see detailed discussion beginning in Section 6.0). The Planning Tool Team then repeated the same process for IP1 structural risk protection projects, with an initial range from \$7.5B to \$15B in \$2.5B increments. Adding nonstructural projects to the mix, the CPRA Team increased the budget range from \$10B to \$17.5B, again in \$2.5B increments. Given alternative performance and a historic parallelism of restoration and risk projects, CPRA selected a final IP1 risk budget of \$12.5B to then explore outcome constraints (see Section 5.4 below).

For IP2, the Planning Tool first evaluated structural and nonstructural risk reduction projects with a budget range of $10B to $17.5B with $2.5B increments. As above, the cost-effectiveness of alternatives versus other considerations had a maximum at $12.5B for IP2 risk. Given remaining resources and projects, budgets of $8.5B and $9.5B were considered for IP2 restoration, with $8.5B selected.

5.4 OUTCOME CONSTRAINTS

The Planning Tool is flexible and can have its objective functions adjusted by constraints to ensure a desired mixture of projects is selected. In this way, the Planning Tool does not simply pick the most cost-effective projects first. For example, if a particular type of project does not have as high of a cost-effectiveness in terms of land (for restoration projects) or EADD and EASD (for risk reduction projects) as others, the Planning Tool could define alternatives requiring a minimum amount of expenditure on each project type to ensure sufficient project diversity. The same procedure could be used to provide an appropriate geographic distribution of benefits. This neither occurred in the 2017 Coastal Master Plan process, nor the 2023 analysis, which helped maintain simplicity and clarity to the Planning Tool's decision drivers.

A key methodological decision for the 2023 Coastal Master Plan was whether to include a constraint on land sustainability – or the concept that projects should have positive returns in their last decade as opposed to potentially being overcome by FWOA effects as they enter Year 50. Figure 22 provides a project comparison dashboard to understand the AAL produced by a project in the last decade under each environmental scenario versus the AAL over the entire 50-year period. A higher ratio, further to the right on the x-axis, indicates that the project creates more land on average overall, whereas higher on the y-axis indicates more land on average is produced later. Projects with negative benefits in either period are not considered sustainable and were not included in the analysis. The Planning Tool Team assessed a few alternatives with a land sustainability constraint, but the selected projects tended to sacrifice too much overall performance for more benefits in later years. Given almost all projects with dis-benefits were in the lower left quadrant, they would not be selected in our optimization runs, and the CPRA Team decided not to implement the constraint in 2023.



			IP 1					
			Avg. Ann Land D5		Avg Annual Land Overall		LSI Ratio (Positive Values Only)	
Project ID	Project Name	Project Type	S07: (Lower)	S08: (Higher)	S07: (Lower)	S08: (Higher)	S07: (Lower)	S08: (Higher)
1300000	Mauvais Bois Ridge Restoration	Ridge Restoration	3.0M	1.7M	1.0M	2.1M	3.01	0.80
1320000	Bayou Pointe Aux Chenes Ridge Re..	Ridge Restoration	0.8M	0.6M	0.3M	0.4M	2.45	1.45
1280000	Bayou Dularge Ridge Restoration	Ridge Restoration	0.2M	0.6M	0.1M	0.2M	2.81	2.46
12300021230000	Belle Pass-Golden Meadow Marsh ..	Marsh Creation	3.3M	8.3M	1.7M	3.5M	1.97	2.39
12300031230000	Belle Pass-Golden Meadow Marsh ..	Marsh Creation	5.8M	14.3M	3.0M	6.0M	1.96	2.38

Figure 22. Project land sustainability comparison in both IPs under both environmental scenarios.

5.5 NONSTRUCTURAL PARTICIPATION CONSTRAINTS

A given nonstructural program will not necessarily be applied to all structures that meet the criteria discussed above in Section 3.3 within a particular master plan community due to owner preferences or physical/financial infeasibility. The participation rate, therefore, will be less than 100%, but it is unknown how much less it might be. The Planning Tool Team implemented this uncertainty in 2023 as an implementation constraint. For IP1, the selected nonstructural variant either had participation limited to 50% or 75%. Upon reviewing the alternative outcomes, the CPRA Team opted for a 75% participation rate so as to provide a somewhat realistic but not onerous constraint, which was similar to the 80% participation rate assumed for the 2017 Coastal Master Plan.

For IP2, the Planning Tool Team considered two potential impacts to participation rate: 1) whether either a structural or nonstructural project was selected in IP1, or 2) whether the community was associated with a structural project. In collaboration with CPRA we developed two constraint options. First, to assess the potential impact of community characteristics on nonstructural participation rate, we considered whether the community was associated with a structural risk reduction project in IP1, and whether either that structural or nonstructural project was selected in IP1. If it was, and the structural project was selected in IP1, then nonstructural participation in that community was assumed to be only 25%. If either the nonstructural project or neither nonstructural or structural project was selected, the participation rate was assumed to be 50% or 75%, depending on the amount of residual risk available to be addressed at a given cost-effectiveness. For communities that were not associated with structural projects, Table 5 shows how the Planning Tool Team implemented the two constraint options, for those places who had nonstructural projects selected in IP1.

Table 5. Nonstructural Participation Rate Options

IS THE COMMUNITY ASSOCIATED WITH A STRUCTURAL PROJECT?	WAS A (NON)STRUCTURAL PROJECT SELECTED IN IP1?	PARTICIPATION RATE	
		OPTION 1	OPTION 2
NONSTRUCTURAL COMMUNITIES ASSOCIATED WITH STRUCTURAL PROJECTS	STRUCTURAL PROJECT SELECTED IN IP1	25%	25%
	NONSTRUCTURAL PROJECT SELECTED IN IP1	50/75%	50/75%
	NEITHER NONSTRUCTURAL NOR STRUCTURAL PROJECT SELECTED IN IP1	50/75%	50/75%
NONSTRUCTURAL COMMUNITIES NOT ASSOCIATED WITH STRUCTURAL PROJECTS	NONSTRUCTURAL PROJECT SELECTED IN IP1	25%	50/75%
	NONSTRUCTURAL PROJECT NOT SELECTED IN IP1	50/75%	50/75%

5.6 ALTERNATIVE SPECIFICATIONS

For the alternative formulation function, CPRA and the Planning Tool Team developed specifications for each alternative to be formulated. The specifications are recorded in an Excel-based table and include the following information:

- Metadata about the alternative
    - Intent narrative
    - Date of formulation
    - Date/version of data
- Description of objective function
- Budget scenario
- Environmental scenario or robust indicator (for formulation)
- Levee fragility assumption contribution to risk
- Land building certainty assumption (determined through the sensitivity analysis)
- Cost uncertainty assumption (determined through the sensitivity analysis)
- Outcome constraints (if any)
- CPRA-specified project inclusions or exclusions (if any)

In the Planning Tool database, each alternative is assigned a unique ID number so that alternative results can be cross-referenced to the specifications used to formulate them. In brief, the alternative ID is a concatenation of variables that track potential optimization decisions across a variety of futures:

1. Source Data ID – a tracking number for data pulled from the PDD
2. Group ID – an index used to indicate a set of alternatives used to explore an intended policy outcome such as a robust alternative or set of constraints
3. Budget ID – the size of the budget and how it is distributed between IPs
4. Objective Function ID – the objective of the optimization balancing between restoration (e.g., maximize land) and risk (e.g., minimize damages)
5. Optimization ID – the process for running the optimization, such as regular optimization, robust first period, robust second period, or all periods fixed
6. Constraint ID – which of the constraints were used to shape the selection of complementary, exclusive, or preferential projects across restoration, risk, sediment, river flow, and other metric constraints
7. Environmental Scenario ID
8. Fragility Scenario ID
9. Pumping Scenario ID
10. Landscape Uncertainty ID
11. Cost Estimate Uncertainty ID

The alternative specification also includes string variables that offer data version controls, plain-text descriptive names, or other process notes via CSV files that were cross-referenced in Tableau for tracking and display purposes.

5.7 OPTIMIZATION OUTPUTS

For each alternative, the Planning Tool defines the projects to implement and estimates the expected outcomes coastwide with respect to key metrics for each alternative. Expected outcomes for alternatives are calculated using an additive assumption (where project benefits are simply added together without accounting for any potential interactions), per the following formula:

$$Expected\_outcome_{m,y,r} = FWOA_{m,y,r} + \sum_{p} Project\_effect_{p,m,y,r}$$

where *FWOA* is the future without action outcome; *m* is a specific ecosystem metric (e.g., land); *y* = year; *r* = region; *p* = selected projects from the alternative.

Note that the effects of a risk reduction project on EADD or EASD is generally negative or risk reducing. The expected outcome calculation is performed only for those metrics that have FWOA values and can be reasonably assumed to be additive. All outputs generated are assessed and stored in the Planning Tool database.

5.8 FORMULATING ROBUST ALTERNATIVES

For both the 2012 and 2017 Coastal Master Plans, an ad hoc process was used to evaluate the project selection under the different scenarios and then decide which alternative to use as the final plan. For 2023, a new approach was developed that is more consistent with best practice from DMDU literature.[7]

In brief, this approach first identifies “high-confidence” projects for IP1. The Planning Tool does this by formulating alternatives for each of the two environmental scenarios – called “optimal” alternatives. Selected projects common to both optimal alternatives are high-confidence projects. The Planning Tool then iteratively increases the IP1 budgets for each optimal alternative until a set of common projects (high-confidence projects) are defined that expend that original amount of funding.

The 2023 Coastal Master Plan considered, but did not apply, binding outcome constraints to high-confidence projects such as land sustainability. Should that have been the case (as it may be in the future, or if other metrics such as species protection were to be considered), then the Planning Tool Team would have:

- Incrementally increase the constraints for the scenario-specific alternatives until the robust alternative meets all constraints
- Lower the constraints and acknowledge that there may not be a set of projects that meet all constraints in both scenarios
- Apply ‘rules’ to include projects that may be selected in only one project but can help ensure that the robust alternative meets all constraints.

Once a full set of high-confidence IP1 projects is selected using all available funds, these projects are passed along to the predictive models to re-evaluate future conditions assuming these projects will be implemented in IP1 (the Iterative Modeling and Selection mode).[8] Note that project costs may differ across the two environmental scenarios, so the process will ensure that final high-confidence projects do not exceed the IP1 budget in either scenario. Together, the high-confidence projects make up a “robust” alternative that will perform well in both scenarios. Figure 23 shows this process for IP1.

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[7] Note that a strategy that adapts over time in response to future conditions would likely be more robust.

[8] In practice, this was only implemented for restoration projects.

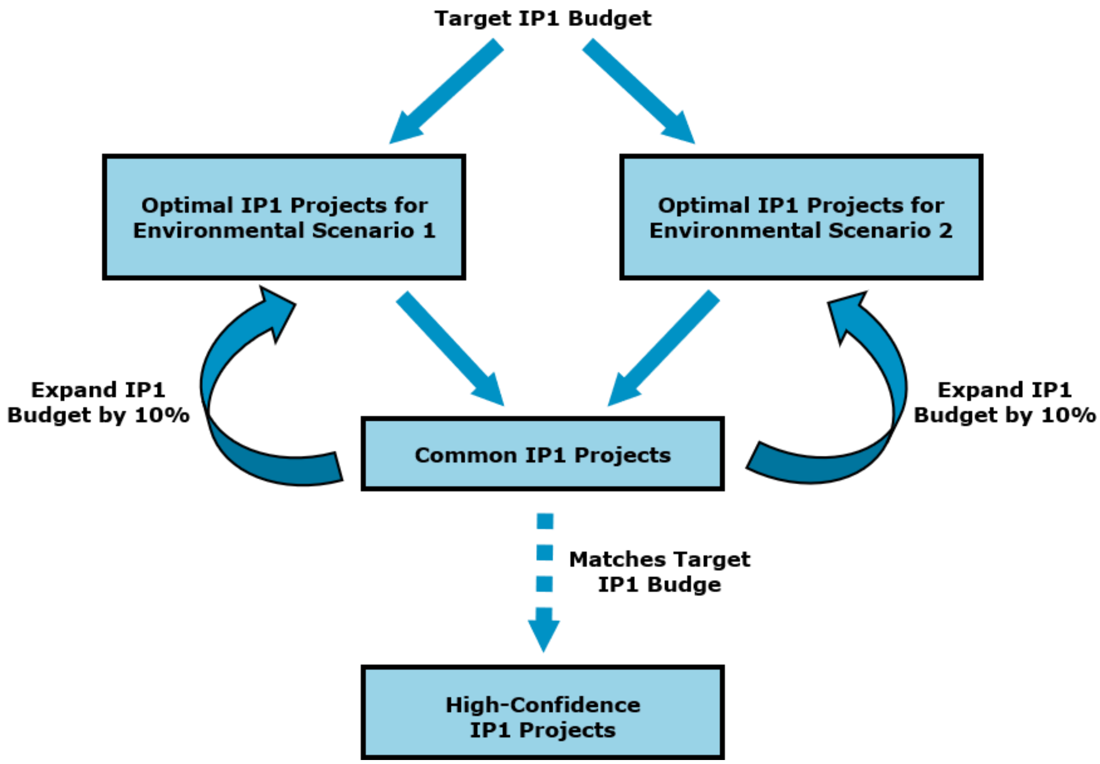

Figure 23. Illustration of iterative process to identify high-confidence projects.

One remaining question was whether the projects should be fixed after each iteration, or free to be unselected. Fixing projects after each iteration is sensitive to the size of the budget increment; however, allowing projects to be reselected (free) could lead to a less optimal solution as the tool replaces initially selected large projects that might not have strong benefits in one of the scenarios with a lot of small projects that emerge to be in common with larger budgets. The Planning Tool Team's testing showed that the deleterious effect of the free approach was small, on the order of one or two projects. As a result, we established a hybrid approach to limit the arbitrariness of fixed and potential sub-optimization of the free approach by locking in the first-round selection of common projects, and then allowing the tool to pick freely after that initial iteration. In coastwide and regionalized comparisons, this hybrid method ultimately tracked the free approach, increasing confidence in our optimization constraint.

Figure 24 shows the iterative selection of restoration projects for IP1. The dark squares indicate that a project is selected. Notice that as a project is selected in both scenarios for one budget, it is included in fixed and free formulations of the robust alternative (with the final method represented in the right-most column). For example, amongst diversions, the Atchafalaya River is selected in both environmental scenarios, and so is represented in the robust alternatives, whereas Increase

Atchafalaya Flow and Central Wetlands are selected in only the lower and higher environmental scenario respectively, and therefore are not included in robust alternatives.

PROJECTS SELECTED BY ALTERNATIVE AND IMPLEMENTATION PERIOD

Project Type	Project ID	Project Name	IP1: $12.5B - Tot: $22.5B - S07	IP1: $12.5B - Tot: $22.5B - S08	RFixed - IP1: $13.0B - Tot: $23B - S07	RFree - IP1: $12.5B - Tot: $22.5B - S08	Robust - IP1: $12.5B - Tot: $22.5B
Diversion	1080000	Atchafalaya River Diversi..	■	■	■	■	■
	1390000	Increase Atchafalaya Flo..	■				
	140000	Central Wetlands Diversi..		■			
Hydrologic Restoration	3490000	Cameron-Creole to the Gu..	■	■	■	■	■
	3480000	Calcasieu/Sabine Basin H..	■				
	3240000	Upper Barataria Hydrolog..	■				
	2840000	Grand Bayou Hydrologic R..	■				
	3470000	Mermentau Basin Hydrolo..		■	■	■	■
	3420000	Western Terrebonne Hydr..	■	■	■	■	■
	1130000	Central Terrebonne Hydro..	■	■	■	■	■
Landbridge	3350300	Eastern Terrebonne Land..	■		■	■	■
	3260100	Mid Barataria Landbridge ..		■			
Ridge Restoration	3340000	Bayou L'Ours Ridge Resto..	■	■		■	■
	1270000	Bayou DeCade Ridge Rest..	■	■	■	■	■
	1300000	Mauvais Bois Ridge Resto..	■	■	■	■	■
	2320000	Pecan Island Ridge Restor..	■				
	1280000	Bayou Dularge Ridge Rest..	■		■		
	3400000	Lower Bayou Petit Caillou ..	■		■		
	3180000	Tchefuncte River Restora..	■	■	■	■	■
	3320000	Caminada Headlands Ridg..		■			
Marsh Creation	33900013390000	West Terrebonne Marsh C..	■	■	■	■	■
	34600013460000	Marsh Island Barrier Mar..	■	■	■	■	■
	12300011230000	Belle Pass-Golden Meado..	■	■	■	■	■
	20700012070000	South Grand Chenier Mar..	■	■	■	■	■
	24800012480000	Pointe a la Hache and Carl..	■	■	■	■	■
	33000043300000	East Bayou Lafourche Mar..	■	■	■	■	■
	12300031230000	Belle Pass-Golden Meado..	■	■	■	■	■
	33000013300000	East Bayou Lafourche Mar..	■	■	■	■	■
	33000053300000	East Bayou Lafourche Mar..	■	■	■	■	■
	31300013130000	West Delacroix Marsh Cre..	■	■	■	■	■
	12500011250000	North Terrebonne Bay Ma..	■	■	■	■	■
	22100012210000	East Pecan Island Marsh C..	■	■	■	■	■

Figure 24. Selected IP1 risk reduction projects under robust alternative formulations.

6.0 EVALUATING ALTERNATIVES

When the Planning Tool formulates an alternative, it defines which projects are implemented in each of the IPs. For each alternative, the Planning Tool also calculates the expected outcomes for land, EADD/EASD, and select metrics annually. Other outputs from the alternative formulation calculations include the cost for all restoration and risk reduction projects by IP (constrained by the funding scenarios), as well as the required sediment by source and IP (constrained by the sediment source volumes). These outputs help CPRA and stakeholders understand why the selected projects are selected.

The Planning Tool helps CPRA to compare different alternatives through visualizations that compare project selection across IPs and expected outcomes. Benefits by each alternative are shown by total additional land over time by region and project type, as well as the summary statistic of AAL. Alternatives could also be compared as single curves against each other over time and in summary. These explorations by environmental scenario demonstrated that robustness could be beneficial, as some projects would drop in or out based on the assumed future.

6.1 IP1 – RESTORATION ALTERNATIVES

The Planning Tool Team's exploration of restoration budgets showed increasing effect with an increasing budget, but with a slightly diminishing cost-effectiveness. In general, the observed dynamic was that large, highly cost-effective projects were selected at lower budgets, and the increasing budget simply selected incrementally more marsh creation projects. After testing several variations around the $12.5 billion budget target, Figure 25 compares the optimized IP1 restoration alternatives for the lower and higher environmental scenarios with the final $12.5 billion budget, as well as the fixed then freely selected robust alternative. We see in the two left charts that, as expected, the optimized alternatives perform best if implemented in their intended formulation scenario. The robust alternative, however, largely tracks the higher environmental scenario's effect if implemented in the lower environmental scenario, whereas it strikes a balance in later years between the two scenarios if implemented in the higher environmental scenario. Regional effects vary, with slight difference between the alternatives and scenarios in Pontchartrain/Breton and the Central Coast. The robust alternative, however, shows a buffered effect in Barataria and the Chenier Plain, and avoids a collapse of land creation in Terrebonne that is possible if the lower formulation scenario is implemented in a higher environmental scenario future.

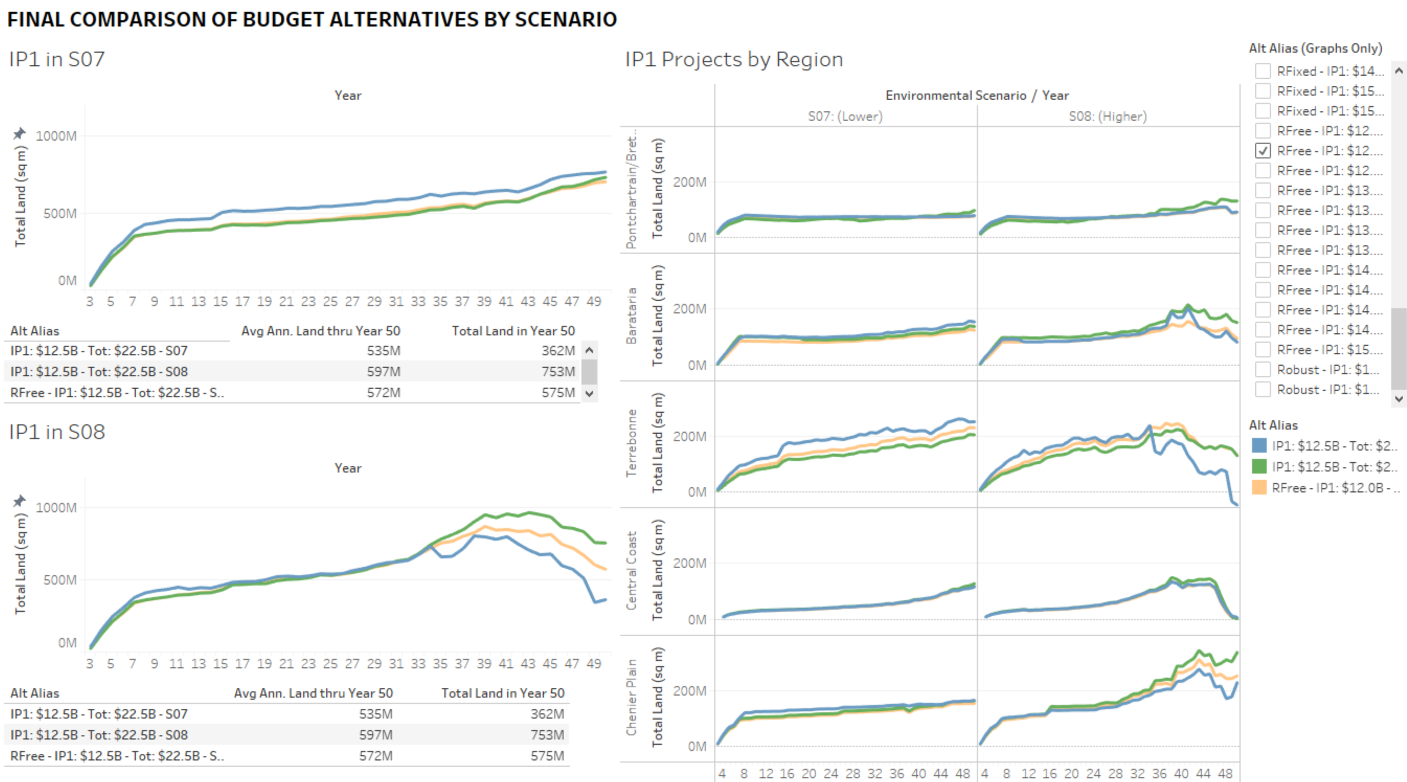

Figure 25. Comparison of lower and higher environmental scenario optimized alternatives with the robust alternative in IP1 with a $12.5B budget.

6.2 IP1 – RISK REDUCTION ALTERNATIVES

The Planning Tool Team's evaluation of risk reduction alternatives (for a given budget) focused on both the relative balance of EADD and EASD as the objective function, as well as the relative participation rate in the nonstructural program. First, Figure 26 shows how project selection differed depending on the relative weight of EADD versus EASD objective functions. For example, for a $12.5B budget, Iberia/St. Mary Upland Levee, Lake Pontchartrain Barrier, Morganza to the Gulf, Slidell Ring Levees, and Upper Barataria Risk Reduction were always selected across the lower and higher environmental scenario. Continuing with the lower environmental scenario alone, with 100% weight on EADD, no additional projects were selected. With a 30% weight shifted to EASD, Braithwaite to White Ditch was chosen, and there was no change with the weight increased to 50%. With either 70% or 100% weight on EASD, Franklin and Vicinity was added. Given stability around an even weighting, and absent a theoretical reason to bias more toward EADD or EASD, the CPRA Team selected a EADD 50% EASD 50% balance. The structural project selection was the same for both environmental scenarios – perhaps due to fewer project choices each with larger budgets – and robust optimization was unnecessary for IP1.

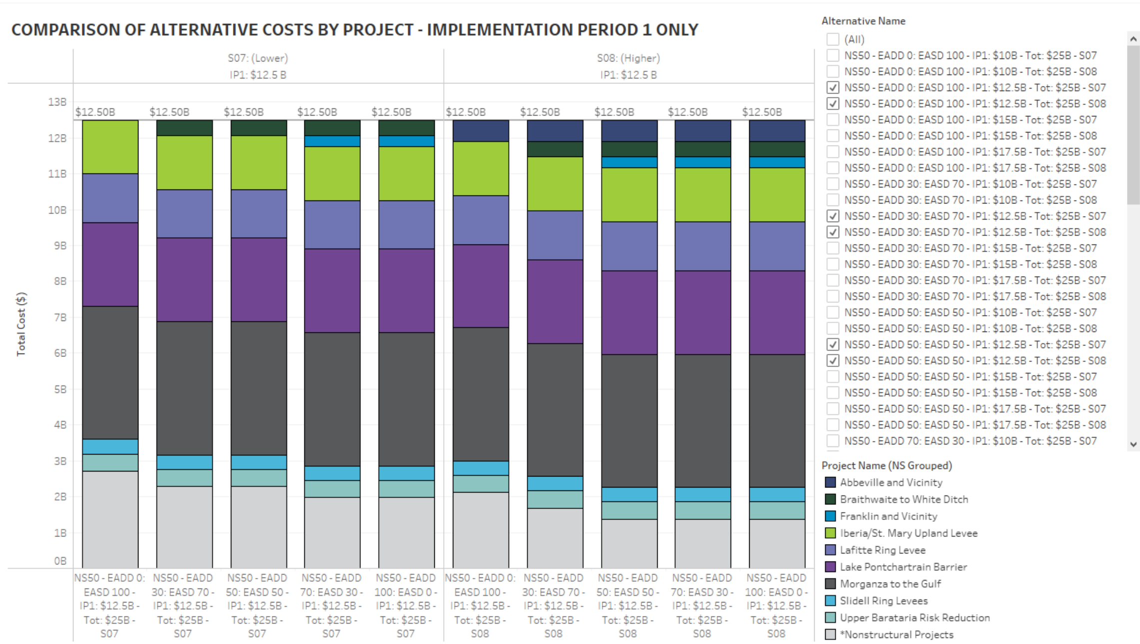

Figure 26. Comparison of lower and higher environmental scenario optimized alternatives with a $12.5B budget for different weightings of EADD and EASD criteria assuming 50% nonstructural program participation.

The remainder of the budget was then used to undertake nonstructural projects, selected by community but rolled back up into a programmatic pool. As no one community would have 100% compliance with a nonstructural risk mitigation program, we evaluated projects at 50% or 75% participation rates. For example, at a $12.5B budget level the higher nonstructural participation rate had the effect of forcing out the Lafitte Ring Levee from selection, except for EASD-preferred higher environmental scenario alternatives. This was important for the consideration of distributional benefits by community, as explored by a series of bar charts across a series of socio-economic attributes such as race/ethnicity, disability, elderly, poverty/low-to-moderate income, and vacancy (see Sections 8.0 and 7.3). Assuming a 75% participation rate for selected communities created a larger nonstructural budget that would afford more flexibility and reduce more residual risk.

Last, we considered differential project selection based on environmental scenario and whether a robust approach would be necessary. As it turned out, the structural project selection was the same for both environmental scenarios – perhaps due to fewer choices with larger budgets – and a robust optimization was unnecessary. Table 6 compares the effect in IP1 of selected structural projects only by environmental scenario and EADD/EASD. In contrast, Figure 27 examines the trend in residual risk and relative to FWOA, inclusive of nonstructural projects.

Table 6. Selected IP1 Alternative Risk Reduction in Year 50 for Structural Projects

	LOWER ENVIRONMENTAL SCENARIO	HIGHER ENVIRONMENTAL SCENARIO
EADD REDUCTION	$6.500B	$8.689B
EASD REDUCTION	5,885 STRUCTURE EQUIVALENTS	7,814 STRUCTURE EQUIVALENTS

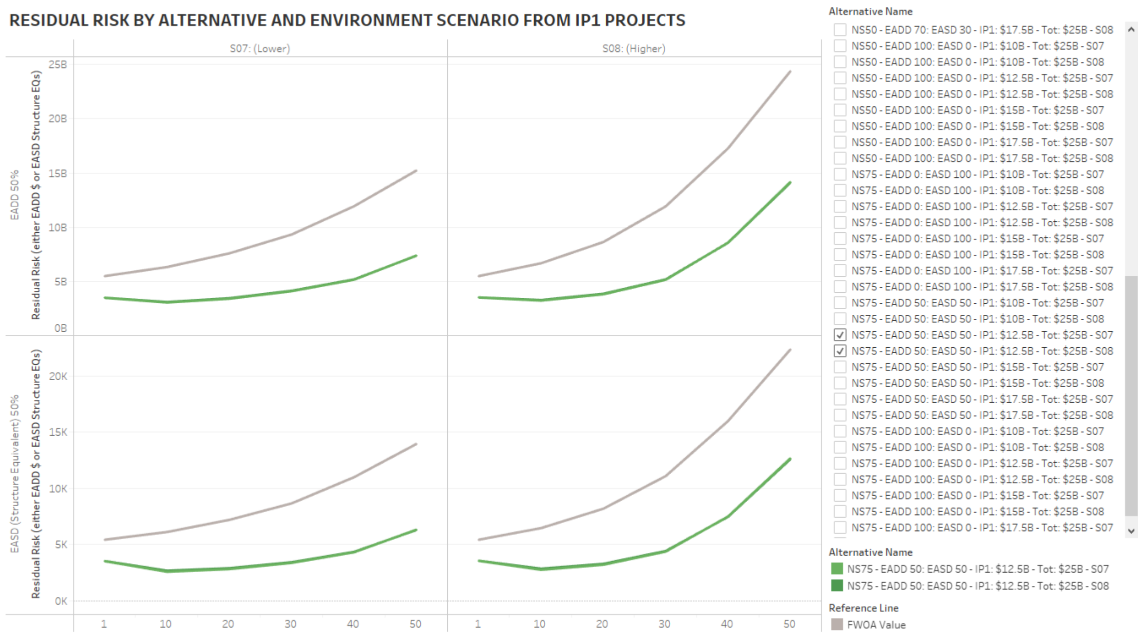

Figure 27. Comparison of residual risk trend relative to FWOA for selected IP1 alternative for both structural projects and nonstructural program

6.3 IP2 – RISK REDUCTION ALTERNATIVES

Given time and modeling constraints, the Planning Tool Team used a *Single Selection Step* process of looking at offset risk project effects for IP2. As the projects have the same dynamics, just delayed, they were neither re-represented in the Planning Tool, nor documented here.

As discussed in Section 5.5, a different variant was used in the IP2 analysis and the nonstructural participation rate was adjusted to account for whether the community was associated with a structural risk reduction project in IP1, and whether either that structural or nonstructural project was selected in IP1. As many of the competitive nonstructural projects were selected in IP1, the higher participation rate forced by Option 2 displaced available budget for structural projects. Option 1 was able to select smaller, but more cost-effective nonstructural projects and therefore include additional structural projects, which increased the overall amount of risk reduction.

Budget tests for IP2 focused on $12.5B and $15B given the findings in IP1 (see Figure 28). Following the same logic of EADD and EASD both receiving 50% weighting, with a budget of $12.5B, Lafitte Ring Levee was the only project in common across both environmental scenarios and nonstructural participation options. As the higher environmental scenario optimization for $12.5B included all the same structural projects of $15B and the additional $2.5B in nonstructural projects yielded little additional benefit, it was the alternative selection. Figure 29 shows the relative effect of the selected projects within each of the alternatives.

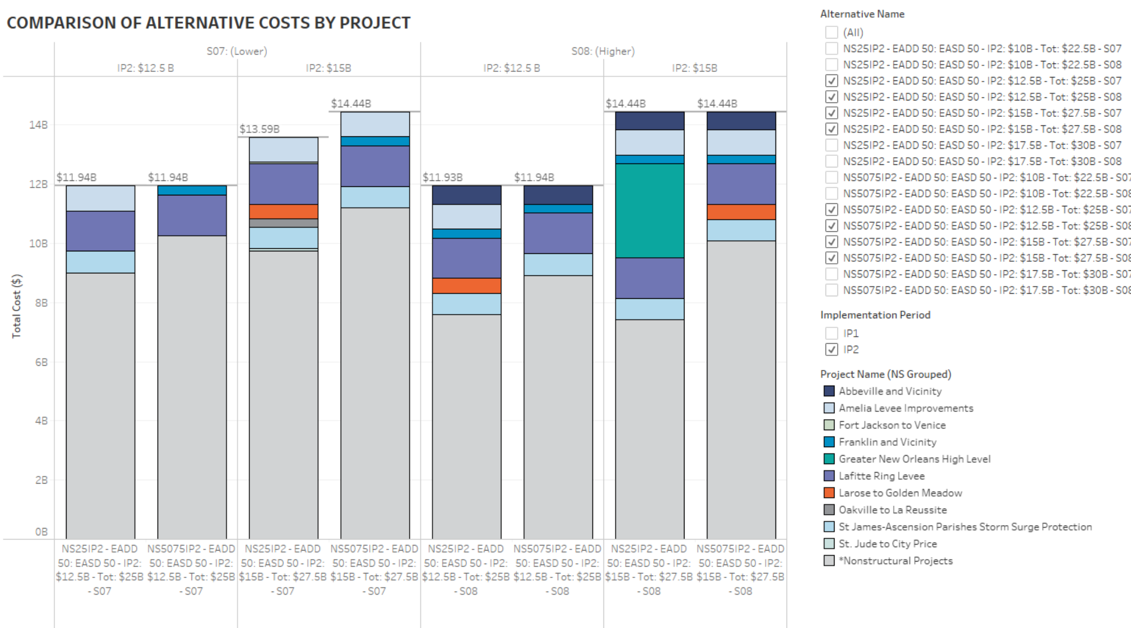

Figure 28. Comparison of lower and higher environmental scenario optimized alternatives with $12.5B and $15B budgets different nonstructural program participation.

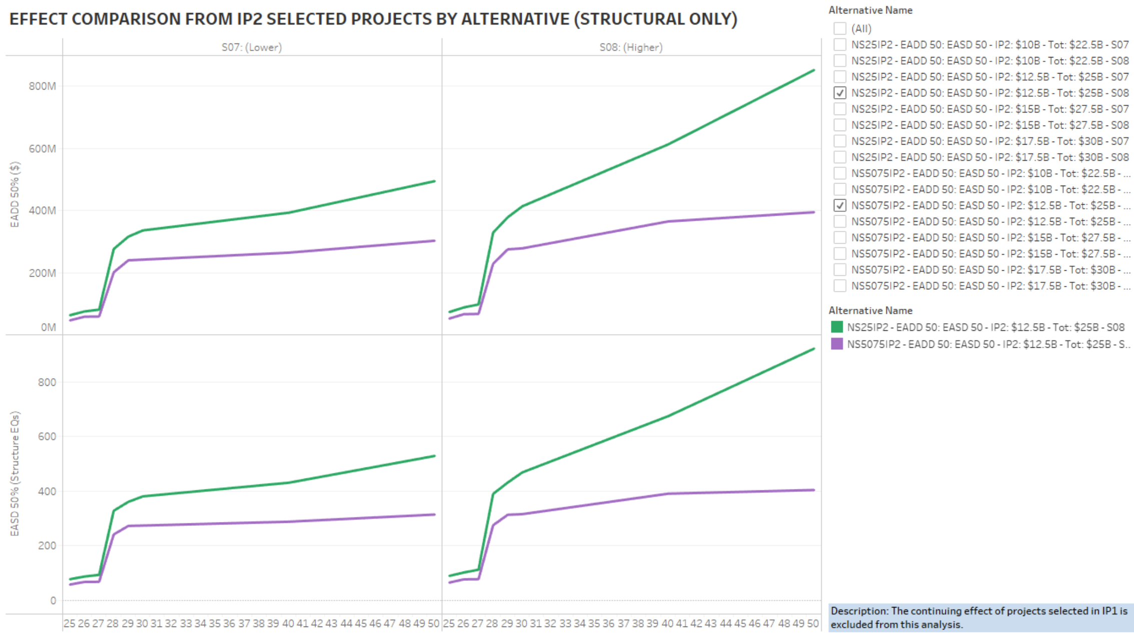

Figure 29. Comparison of effects for IP2 structural projects only based on nonstructural participation rates and formulation environmental scenario with a $12.5B budget.

6.4 IP2 – RESTORATION ALTERNATIVES

With both IP1 restoration and risk projects selected, the CPRA Team and other PDT partners ran the Future with Project for IP2 restoration alternatives. Building on our IP1 findings and experience with IP2 risk alternatives, the Planning Tool Team took a narrow focus on two budgets, $8.5B and $9.5B, using the costs for the higher environmental scenario as a conservative assumption. Like the decision carrying forward an equal weighting for EADD and EASD for IP2 risk, the Planning Tool Team assumed a robust, rather than an environmental scenario-optimized, approach (using the fixed, then free, methods). Increasing the budget by $1B added four projects – Bayou Dularge Ridge Restoration, Golden Triangle Marsh Creation, East Calcasieu Lake Marsh Creation, and North Lake Mechant Marsh Creation. Figure 30 shows only a modest difference in effect with these addition. Given the low cost-effectiveness of the higher budget alternative, the CPRA Team selected the $8.5B alternative.

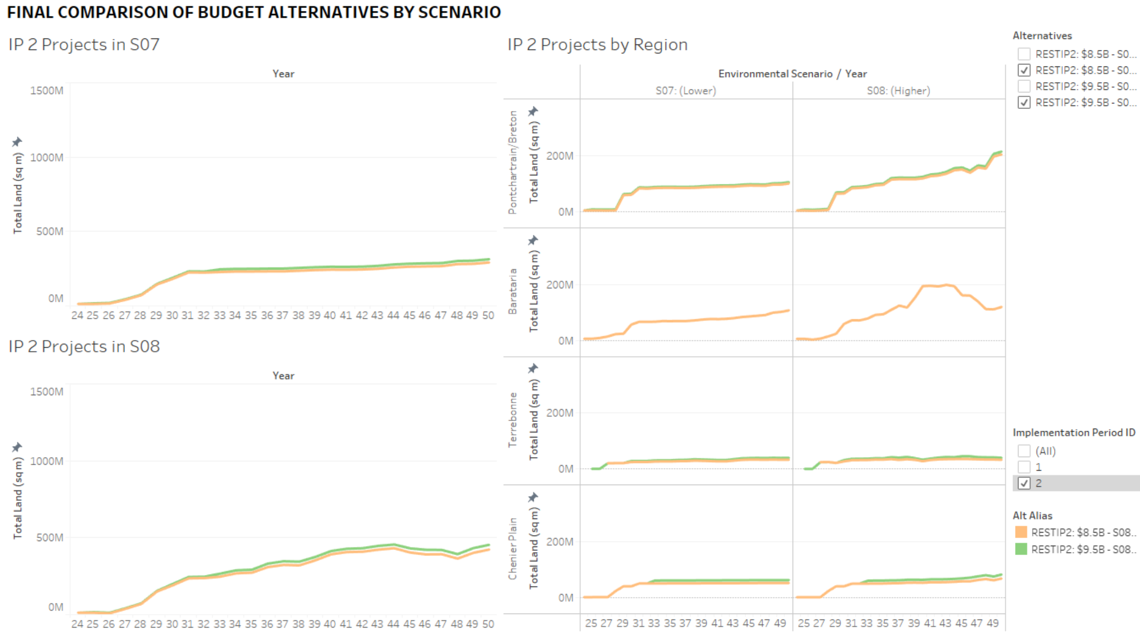

Figure 30. Comparison of $8.5B and $9.5B alternatives under higher environmental scenario formulation.

7.0 RESULTS TO SUPPORT MASTER PLAN DELIBERATIONS

The Planning Tool analyses described above are, by nature, exploratory, and do not present simple conclusions. Projects are numerous and can be compared across different metrics, regions, and time periods. Alternatives are composed of different combinations of projects and have differential effects across the coast. The Planning Tool helps CPRA and stakeholders explore the analytic results, see the key differences, and support deliberations through interactive visualizations and iteration.

The 2023 Draft Coastal Master Plan represents a $50 billion investment in coastal Louisiana over 50 years. It includes $21B for 61 restoration projects and $14B 12 structural risk reduction projects distributed across the coast (see Figure 31). In addition, the master plan allocates $11 billion for nonstructural risk reduction and the remainder for programmatic restoration projects. In January 2023, CPRA began to engage in consultations with communities throughout the state to share the Planning Tool's project selection methodology and receive stakeholder feedback on topics that may include other landscape metrics, equity concerns, or implementation considerations. The CPRA Team will then compare the participatory constituent inputs to the selected draft alternative in its deliberations to generate the final 2023 Coastal Master Plan.

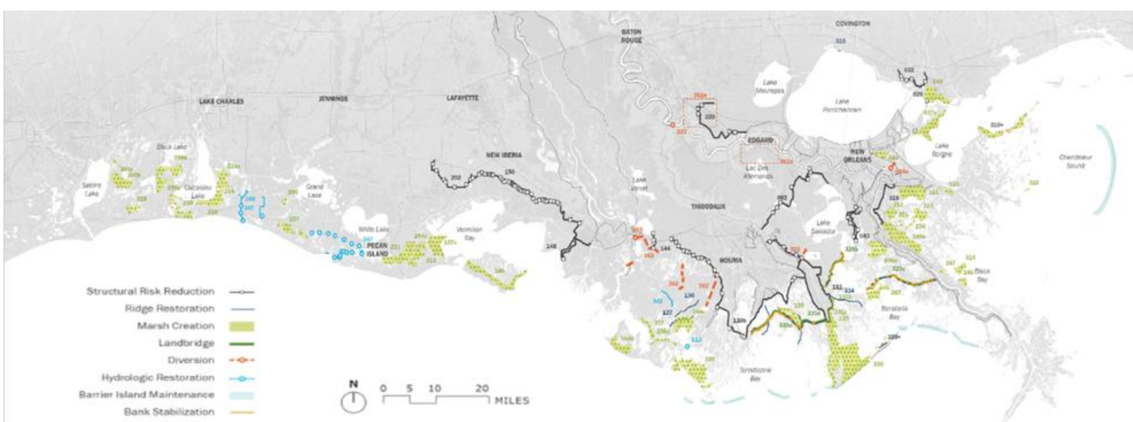

Figure 31. Projects selected in the 2023 Draft Coastal Master Plan.

Under the lower environmental scenario, implementation of the plan would result in over 7,000 avoided annual structure losses, over $7.5 billion in avoided annual damages, and 310 square miles of avoided land loss. For the higher scenario, the results would be over 9,500 avoided annual structure losses, $11 billion in avoided annual damages and 230 square miles of land compared to not implementing the plan.

7.1 SUMMARY OF SELECTED RESTORATION PROJECTS

The CPRA Team, with the support of the Planning Tool Team, selected the robust restoration alternatives for a \$12.5B IP1 and \$8.5B IP2 budget. Figure 32 and Figure 33 show the benefits by region and project type for IP1 and IP2, respectively, under the lower environmental scenario. Figure 34 then shows both IP1 and IP2 projects in combination under both environmental scenarios with the geographic benefits split out. These graphics are helpful for understanding the geographic impacts of the projects as well as the relative mix of strategies across the coast.

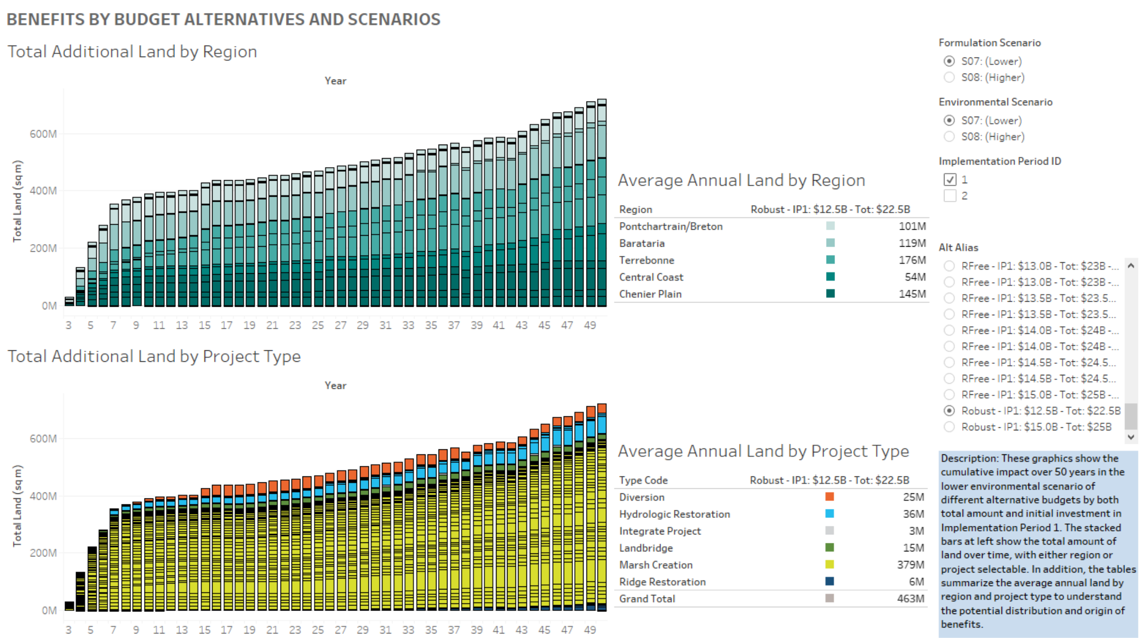

Figure 32. Benefits of the draft master plan selected IP1 restoration projects under the \$12.5B robust alternative formulation and lower environmental scenario.

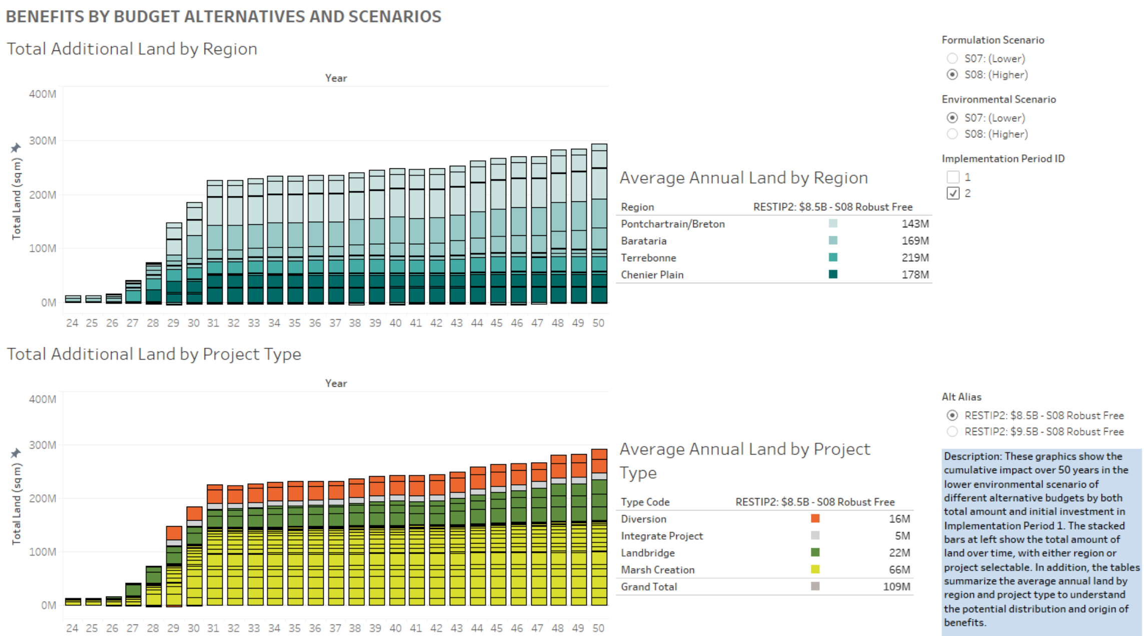

Figure 33. Benefits of the draft master plan selected IP2 restoration projects under the $8.5B robust alternative formulation and lower environmental scenario.

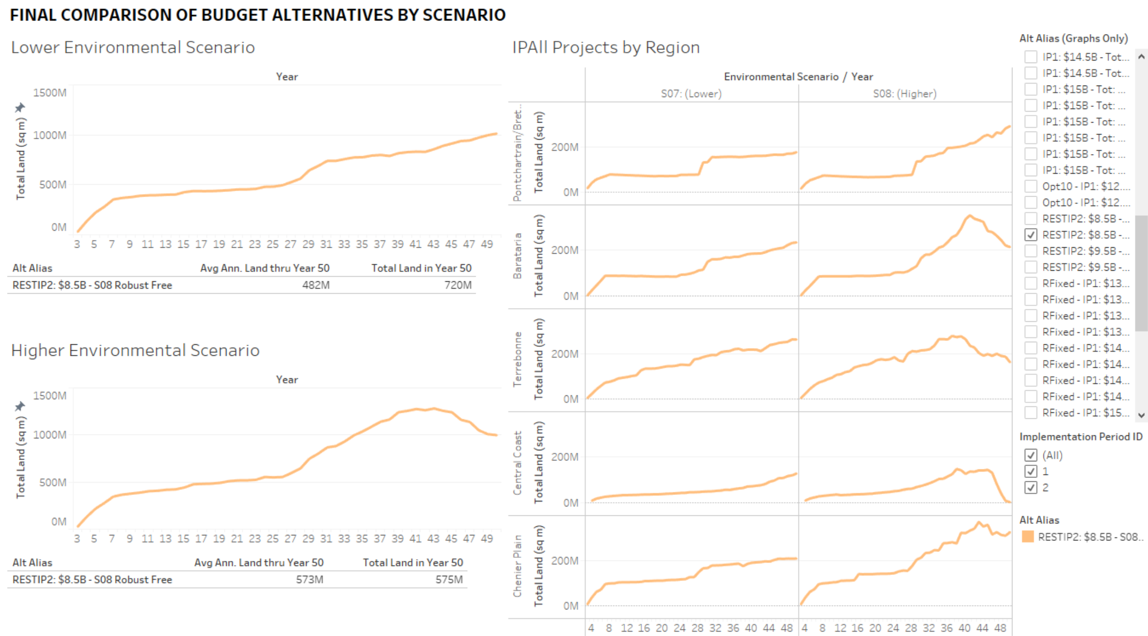

Figure 34. Benefits of the draft master plan alternative selected restoration projects.

7.2 SUMMARY OF SELECTED RISK PROJECTS

The CPRA Team, with the support of the Planning Tool Team, selected the robust alternative for a $12.5B IP1 budget using an even weight of EADD and EASD as objective criteria, assuming a 75% nonstructural program participation rate. The nonstructural program threshold was based on a Year 0, 1% AEP flood elevation and an acquisition target of 14 ft. For IP2, the CPRA Team again selected a $12.5B budget and an evenly weighted objective criteria, but with the nonstructural program threshold using Year 30, 1% AEP flood elevation (again, with an acquisition target of 14 ft). If the nonstructural community was not associated with a structural project, and the nonstructural project was selected in IP1, then the Planning Tool opted to reduce program participation to 25% (all other rules were the same between the two options tested).

Figure 35 and Figure 36 show the effects by project to EADD and EASD for IP1 and IP2, respectively, under both environmental scenarios. Figure 37 then shows both IP1 and IP2 project effects on EADD and EASD in aggregate under both environmental scenarios.

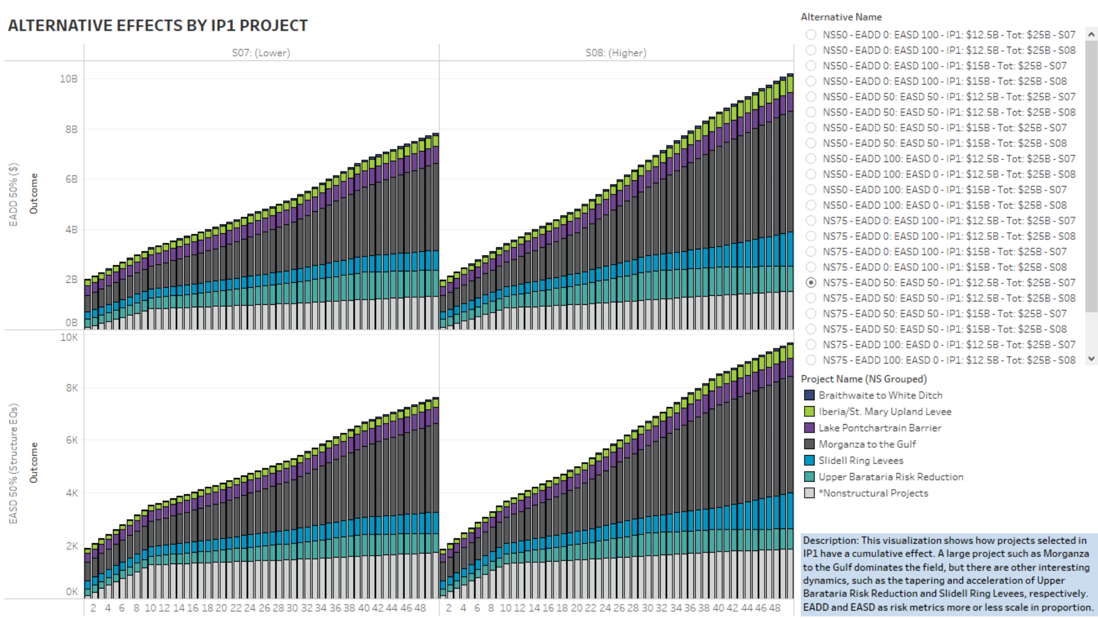

Figure 35. Benefits of the draft master plan selected IP1 risk reduction projects with a $12.5B budget, evenly weighted EADD and EASD criteria, and a 75% nonstructural participation rate.

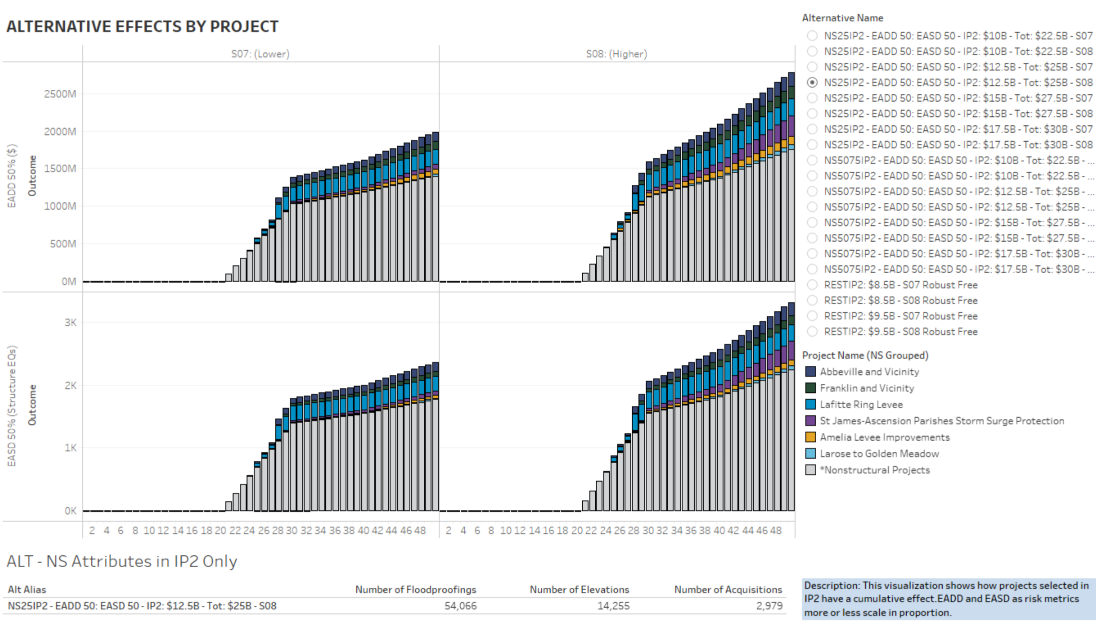

Figure 36. Benefits of the draft master plan selected IP2 risk reduction projects with $12.5B budget, evenly weighted EADD and EASD criteria, and Option 1 participation rate.

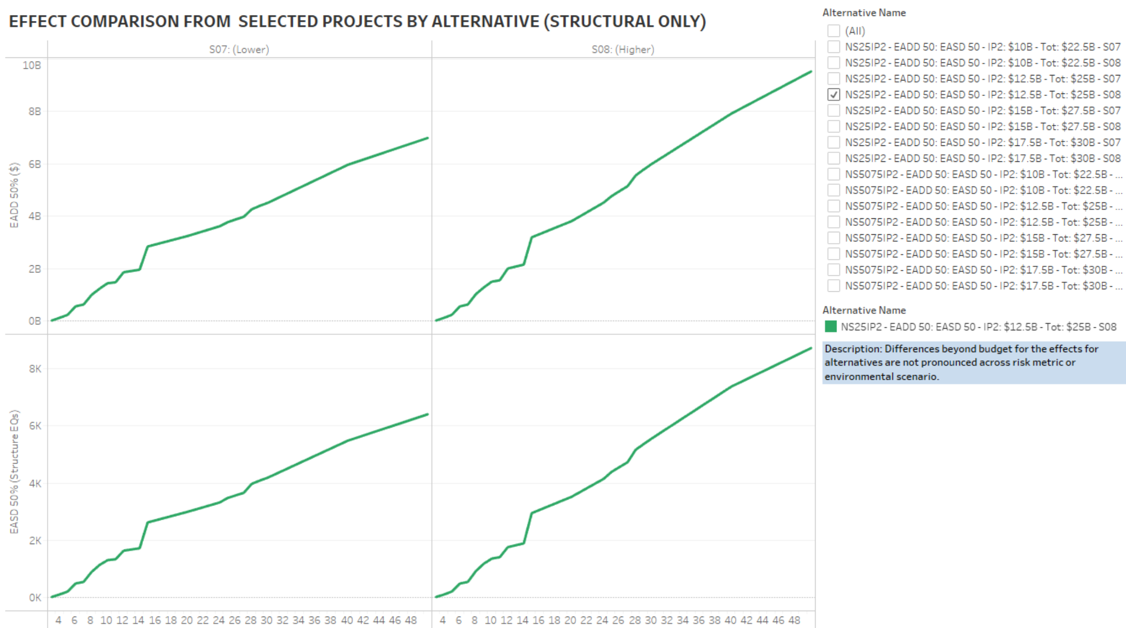

Figure 37. Benefits of the draft master plan alternative selected risk reduction projects.

7.3 ADDITIONAL COMMUNITY-LEVEL EQUITY AND SOCIO-ECONOMIC CONSIDERATIONS

As an additional point of reference, Figure 38 and Figure 39 illustrate the differential location of both FWOA and residual risk in Year 50 for EADD and EASD, respectively, under the lower environmental scenario. While the color ramp scales between the two criteria are not directly proportional, the representation shows slight differences that could support future deliberations at the community level about the nonstructural risk reduction program.

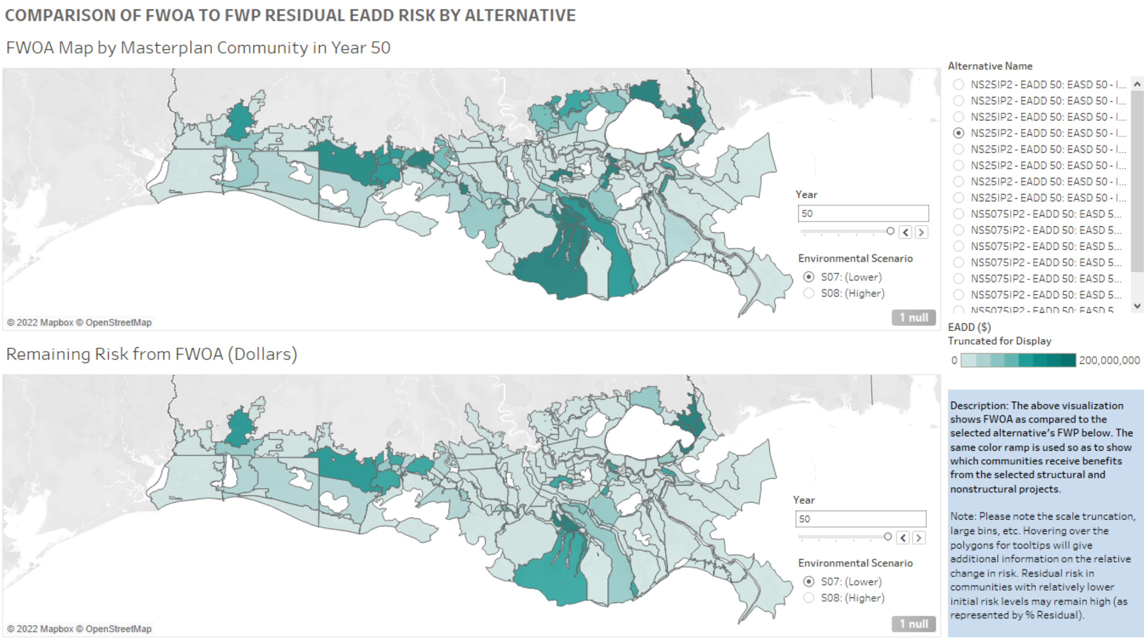

Figure 38. Comparison of residual risk location relative to FWOA by EADD with the lower environmental scenario in Year 50.

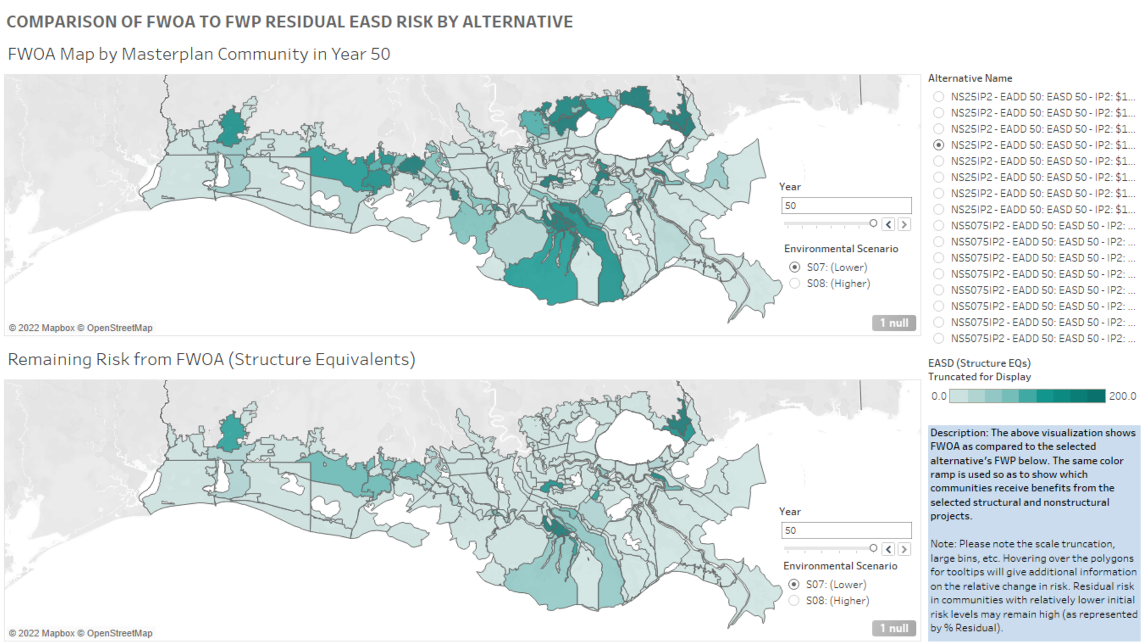

Figure 39. Comparison of residual risk location relative to FWOA by EASD with the lower environmental scenario in Year 50.

An important consideration to the draft master plan's introduction to community stakeholders is understanding the relative equity impact. In exploratory analysis, the Planning Tool Team looked at a number of socio-demographic and economic attributes. For example, Figure 40 and Figure 41 explore the change to FWOA on an EADD basis by community and region to the percentage of the population that is low-to-moderate income or non-white. Additional comparisons are possible, depending on the interests of nonstructural planners and community stakeholders.

Figure 40. Effect of risk reduction projects by EADD on communities by low-to-moderate income population percentage in Year 50 under the lower environmental scenario.

Figure 41. Effect of risk reduction projects by EADD on communities by non-white population percentage in Year 50 under the lower environmental scenario.

8.0 RECOMMENDATIONS FOR FUTURE ANALYSIS

Due to time constraints and some changes to the PDD in order to facilitate the production of the overall master plan document, the Planning Tool Team only conducted a preliminary exploratory analysis of habitat suitability, agricultural impact, traditional fishing access, and oil and gas industry land/water stability. We anticipate that revised versions of these displays will be included in an update by April 2023.

8.1 ADDITIONAL DERIVED METRICS

There are additional metrics used to represent the effects of projects and/or alternatives that are derived from project attributes or results for the ecosystem metrics, risk metrics, or both metrics. Subject to additional Planning Tool Team analysis in the future, they include:

- Agricultural Communities - Risk Reduction
- Agriculture - Sustainability
- Current vs. Future Flood Risk
- Demographics (age, sex, race, income)
- Flood Protection of Strategic Assets
- Historic Properties Inundated
- Land loss around Archeological sites
- Navigation - Inland Protection
- Navigation - Inland Shoaling
- Navigation - River Steerage
- Navigation Channel Access
- Oil and Gas Activities
- Oil and Gas Communities - Risk Reduction
- Traditional Fishing Access to Resources
- Traditional Fishing Communities - Risk Reduction
- Use of Natural Processes

The Planning Tool Team has developed draft visualizations allowing the comparison of several of these metrics at once by community, which will be subject to additional review and feedback from the CPRA Team.

8.2 UNCERTAINTY IN LAND AREA ANALYSIS

There is uncertainty related to how the ICM modeling estimates landscape functions and changes over time. As information is passed from one ICM subroutine to another, the effects of uncertainties on model outputs may grow and amplify or could dampen or be reduced due to temporal or spatial integration (e.g., use of two-week mean salinity in the morphology subroutine based on daily outputs from the hydrology subroutine). This uncertainty is assumed to be independent of the factors accounted for in the environmental scenarios. For example, if the magnitude of relative sea level increases substantially in later decades under a higher scenario, the model prediction of land area will likely be much more sensitive to sea level rise rates than a temporally static model error in mean water level predictions. Severe future environmental scenarios overwhelm and mask uncertainties in the model output caused by model errors.

The ICM modelers will conduct an uncertainty analysis on the FWOA condition for each of the two environmental scenarios by varying different ICM modeling parameters such as annual water level, water level variability, annual mean salinity, organic accretion, and total suspended solids (Meselhe et al., 2021). This analysis will determine the confidence that each 30 m pixel used in the ICM will be land versus water. By aggregating this information to the ecoregion level, the ICM can estimate land outcomes based on different confidence levels:

- Ecoregions where land area that is not sensitive to uncertainty
- Ecoregions that include areas that are sensitive to uncertainty

This information will allow the Planning Tool to explore project selection based on land benefits that are not sensitive to uncertainty – a conservative low-land estimate – and land benefits that include areas that are more sensitive to ICM uncertainty.

In generating FWOA, the ICM determines whether particular pixels (30 m grid) are land or water. The Planning Tool used just one version of the FWOA results, but other runs might show perturbations associated with each environmental scenario that alter the land water balance. If the Planning Tool were to receive a different set of PDD outputs showing benefit areas and induced loss by possibility of being land or water, the Planning Tool could then calculate the relative level of sensitivity of project selection and/or the draft master plan alternative’s effect.

We anticipate that this work would be useful for not only understanding which projects might need more detailed modeling or exploration of benefits upon implementation, but also a better understanding of modeling uncertainties for future iterations of the master plan process.

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Coastal Protection and Restoration Authority Board, and Terrebonne Levee and Conservation District.

10.0 ALTERNATIVES TESTED

ALTERNATIVEID	NAME
IP1 RESTORATION OPTIMIZATION TESTS	
1	IP1: $15B - TOT: $25B - S07
2	IP1: $15B - TOT: $25B - S08
3	IP1: $7.5B - TOT: $25B - S07
4	IP1: $7.5B - TOT: $25B - S08
5	IP1: $10B - TOT: $25B - S07
6	IP1: $10B - TOT: $25B - S08
7	IP1: $12.5B - TOT: $25B - S07
8	IP1: $12.5B - TOT: $25B - S08
9	IP1: $15B - TOT: $20B - S07
10	IP1: $15B - TOT: $20B - S08
11	IP1: $7.5B - TOT: $20B - S07
12	IP1: $7.5B - TOT: $20B - S08
13	IP1: $10B - TOT: $20B - S07
14	IP1: $10B - TOT: $20B - S08
15	IP1: $12.5B - TOT: $20B - S07
16	IP1: $12.5B - TOT: $20B - S08
17	IP1: $12.5B - TOT: $22.5B - S07
18	IP1: $12.5B - TOT: $22.5B - S08
19	IP1: $10B - TOT: $22.5B - S07
20	IP1: $10B - TOT: $22.5B - S08
21	IP1: $7.5B - TOT: $22.5B - S07
22	IP1: $7.5B - TOT: $22.5B - S08
23	IP1: $15B - TOT: $22.5B - S07
24	IP1: $15B - TOT: $22.5B - S08
37	IP1: $13.0B - TOT: $23B - S07
38	IP1: $13.0B - TOT: $23B - S08
57	IP1: $12.875B - TOT: $22.875B - S07
58	IP1: $12.875B - TOT: $22.875B - S08
59	IP1: $12.0B - TOT: $22B - S07
60	IP1: $12.0B - TOT: $22B - S08
61	IP1: $13.5B - TOT: $23.5B - S07
62	IP1: $13.5B - TOT: $23.5B - S08

63	IP1: $14.0B - TOT $24B - S07
64	IP1: $14.0B - TOT $24B - S08
65	IP1: $14.5B - TOT: $24.5B - S07
66	IP1: $14.5B - TOT: $24.5B - S08
IP1 RESTORATION LAND SUSTAINABILITY TESTS	
27	OPT10 - IP1: $12.5B - TOT: $22.5B - S07
28	OPT10 - IP1: $12.5B - TOT: $22.5B - S08
IP1 RESTORATION ROBUSTNESS AND BUDGET TESTS	
25	DEMO RFIXED - IP1: $12.5B - TOT: $22.5B - S07
26	DEMO RFIXED - IP1: $12.5B - TOT: $22.5B - S08
29	ROBUST - IP1: $12.5B - TOT: $22.5B
30	RFREE - IP1: $12.5B - TOT: $22.5B - S08
31	RFREE - IP1: $12.0B - TOT: $22B - S07
32	RFREE - IP1: $12.0B - TOT: $22B - S08
33	RFREE - IP1: $13.0B - TOT: $23B - S07
34	RFREE - IP1: $13.0B - TOT: $23B - S08
35	RFIXED - IP1: $13.0B - TOT: $23B - S07
36	RFIXED - IP1: $13.0B - TOT: $23B - S08
39	RFREE - IP1: $13.5B - TOT: $23.5B - S07
40	RFREE - IP1: $13.5B - TOT: $23.5B - S08
41	RFREE - IP1: $14.0B - TOT: $24B - S07
42	RFREE - IP1: $14.0B - TOT: $24B - S08
43	RFREE - IP1: $14.5B - TOT: $24.5B - S07
44	RFREE - IP1: $14.5B - TOT: $24.5B - S08
45	ROBUST - IP1: $15.0B - TOT: $25B
46	RFREE - IP1: $15.0B - TOT: $25B - S08
47	RFIXED - IP1: $13.5B - TOT: $23.5B - S07
48	RFIXED - IP1: $13.5B - TOT: $23.5B - S08
49	RFIXED - IP1: $14.0B - TOT: $24B - S07
50	RFIXED - IP1: $14.0B - TOT: $24B - S08
51	RFIXED - IP1: $14.5B - TOT: $24.5B - S07
52	RFIXED - IP1: $14.5B - TOT: $24.5B - S08
53	RFIXED - IP1: $15.0B - TOT: $25B - S07
54	RFIXED - IP1: $15.0B - TOT: $25B - S08
55	RFIXED - IP1: $12.5B - TOT: $22.5B - S07
56	RFIXED - IP1: $12.5B - TOT: $22.5B - S08

IP1 RISK REDUCTION OPTIMIZATION TESTS (EADD ONLY)	
67	SR ONLY - IP1: $7.5B - TOT: $25B - S07
68	SR ONLY - IP1: $7.5B - TOT: $25B - S08
69	SR ONLY - IP1: $10B - TOT: $25B - S07
70	SR ONLY - IP1: $10B - TOT: $25B - S08
71	SR ONLY - IP1: $12.5B - TOT: $25B - S07
72	SR ONLY - IP1: $12.5B - TOT: $25B - S08
73	SR ONLY - IP1: $15B - TOT: $25B - S07
74	SR ONLY - IP1: $15B - TOT: $25B - S08
75	SR ONLY - IP1: $17.5B - TOT: $25B - S07
76	SR ONLY - IP1: $17.5B - TOT: $25B - S08
77	SR ONLY - IP1: $15B - TOT: $27.5B - S07
78	SR ONLY - IP1: $15B - TOT: $27.5B - S08
79	SR ONLY - IP1: $15B - TOT: $30B - S07
80	SR ONLY - IP1: $15B - TOT: $30B - S08
IP1 RISK REDUCTION EADD AND EASD WITH NONSTRUCTURAL TESTS	
81	EADD - SR AND NS - IP1: $10B - TOT: $25B - S07
82	EADD - SR AND NS - IP1: $10B - TOT: $25B - S08
83	EADD - SR AND NS - IP1: $12.5B - TOT: $25B - S07
84	EADD - SR AND NS - IP1: $12.5B - TOT: $25B - S08
85	EADD - SR AND NS - IP1: $15B - TOT: $25B - S07
86	EADD - SR AND NS - IP1: $15B - TOT: $25B - S08
87	EADD - SR AND NS - IP1: $17.5B - TOT: $25B - S07
88	EADD - SR AND NS - IP1: $17.5B - TOT: $25B - S08
89	EASD - SR AND NS - IP1: $10B - TOT: $25B - S07
90	EASD - SR AND NS - IP1: $10B - TOT: $25B - S08
91	EASD - SR AND NS - IP1: $12.5B - TOT: $25B - S07
92	EASD - SR AND NS - IP1: $12.5B - TOT: $25B - S08
93	EASD - SR AND NS - IP1: $15B - TOT: $25B - S07
94	EASD - SR AND NS - IP1: $15B - TOT: $25B - S08
95	EASD - SR AND NS - IP1: $17.5B - TOT: $25B - S07
96	EASD - SR AND NS - IP1: $17.5B - TOT: $25B - S08
IP1 RISK REDUCTION EADD/EASD WEIGHT AND NONSTRUCTURAL PARTICIPATION RATE TESTS	
97	NS50 - EADD 100: EASD 0 - IP1: $10B - TOT: $25B - S07
98	NS50 - EADD 100: EASD 0 - IP1: $10B - TOT: $25B - S08
99	NS50 - EADD 100: EASD 0 - IP1: $12.5B - TOT: $25B - S07

100	NS50 - EADD 100: EASD 0 - IP1: $12.5B - TOT: $25B - S08
101	NS50 - EADD 100: EASD 0 - IP1: $15B - TOT: $25B - S07
102	NS50 - EADD 100: EASD 0 - IP1: $15B - TOT: $25B - S08
103	NS50 - EADD 100: EASD 0 - IP1: $17.5B - TOT: $25B - S07
104	NS50 - EADD 100: EASD 0 - IP1: $17.5B - TOT: $25B - S08
105	NS50 - EADD 0: EASD 100 - IP1: $10B - TOT: $25B - S07
106	NS50 - EADD 0: EASD 100 - IP1: $10B - TOT: $25B - S08
107	NS50 - EADD 0: EASD 100 - IP1: $12.5B - TOT: $25B - S07
108	NS50 - EADD 0: EASD 100 - IP1: $12.5B - TOT: $25B - S08
109	NS50 - EADD 0: EASD 100 - IP1: $15B - TOT: $25B - S07
110	NS50 - EADD 0: EASD 100 - IP1: $15B - TOT: $25B - S08
111	NS50 - EADD 0: EASD 100 - IP1: $17.5B - TOT: $25B - S07
112	NS50 - EADD 0: EASD 100 - IP1: $17.5B - TOT: $25B - S08
113	NS50 - EADD 50: EASD 50 - IP1: $10B - TOT: $25B - S07
114	NS50 - EADD 50: EASD 50 - IP1: $10B - TOT: $25B - S08
115	NS50 - EADD 50: EASD 50 - IP1: $12.5B - TOT: $25B - S07
116	NS50 - EADD 50: EASD 50 - IP1: $12.5B - TOT: $25B - S08
117	NS50 - EADD 50: EASD 50 - IP1: $15B - TOT: $25B - S07
118	NS50 - EADD 50: EASD 50 - IP1: $15B - TOT: $25B - S08
119	NS50 - EADD 50: EASD 50 - IP1: $17.5B - TOT: $25B - S07
120	NS50 - EADD 50: EASD 50 - IP1: $17.5B - TOT: $25B - S08
121	NS50 - EADD 70: EASD 30 - IP1: $10B - TOT: $25B - S07
122	NS50 - EADD 70: EASD 30 - IP1: $10B - TOT: $25B - S08
123	NS50 - EADD 70: EASD 30 - IP1: $12.5B - TOT: $25B - S07
124	NS50 - EADD 70: EASD 30 - IP1: $12.5B - TOT: $25B - S08
125	NS50 - EADD 70: EASD 30 - IP1: $15B - TOT: $25B - S07
126	NS50 - EADD 70: EASD 30 - IP1: $15B - TOT: $25B - S08
127	NS50 - EADD 70: EASD 30 - IP1: $17.5B - TOT: $25B - S07
128	NS50 - EADD 70: EASD 30 - IP1: $17.5B - TOT: $25B - S08
129	NS50 - EADD 30: EASD 70 - IP1: $10B - TOT: $25B - S07
130	NS50 - EADD 30: EASD 70 - IP1: $10B - TOT: $25B - S08
131	NS50 - EADD 30: EASD 70 - IP1: $12.5B - TOT: $25B - S07
132	NS50 - EADD 30: EASD 70 - IP1: $12.5B - TOT: $25B - S08
133	NS50 - EADD 30: EASD 70 - IP1: $15B - TOT: $25B - S07
134	NS50 - EADD 30: EASD 70 - IP1: $15B - TOT: $25B - S08
135	NS50 - EADD 30: EASD 70 - IP1: $17.5B - TOT: $25B - S07

136	NS50 - EADD 30: EASD 70 - IP1: $17.5B - TOT: $25B - S08
137	NS75 - EADD 100: EASD 0 - IP1: $10B - TOT: $25B - S07
138	NS75 - EADD 100: EASD 0 - IP1: $10B - TOT: $25B - S08
139	NS75 - EADD 100: EASD 0 - IP1: $12.5B - TOT: $25B - S07
140	NS75 - EADD 100: EASD 0 - IP1: $12.5B - TOT: $25B - S08
141	NS75 - EADD 100: EASD 0 - IP1: $15B - TOT: $25B - S07
142	NS75 - EADD 100: EASD 0 - IP1: $15B - TOT: $25B - S08
143	NS75 - EADD 100: EASD 0 - IP1: $17.5B - TOT: $25B - S07
144	NS75 - EADD 100: EASD 0 - IP1: $17.5B - TOT: $25B - S08
145	NS75 - EADD 0: EASD 100 - IP1: $10B - TOT: $25B - S07
146	NS75 - EADD 0: EASD 100 - IP1: $10B - TOT: $25B - S08
147	NS75 - EADD 0: EASD 100 - IP1: $12.5B - TOT: $25B - S07
148	NS75 - EADD 0: EASD 100 - IP1: $12.5B - TOT: $25B - S08
149	NS75 - EADD 0: EASD 100 - IP1: $15B - TOT: $25B - S07
150	NS75 - EADD 0: EASD 100 - IP1: $15B - TOT: $25B - S08
151	NS75 - EADD 0: EASD 100 - IP1: $17.5B - TOT: $25B - S07
152	NS75 - EADD 0: EASD 100 - IP1: $17.5B - TOT: $25B - S08
153	NS75 - EADD 50: EASD 50 - IP1: $10B - TOT: $25B - S07
154	NS75 - EADD 50: EASD 50 - IP1: $10B - TOT: $25B - S08
155	NS75 - EADD 50: EASD 50 - IP1: $12.5B - TOT: $25B - S07
156	NS75 - EADD 50: EASD 50 - IP1: $12.5B - TOT: $25B - S08
157	NS75 - EADD 50: EASD 50 - IP1: $15B - TOT: $25B - S07
158	NS75 - EADD 50: EASD 50 - IP1: $15B - TOT: $25B - S08
159	NS75 - EADD 50: EASD 50 - IP1: $17.5B - TOT: $25B - S07
160	NS75 - EADD 50: EASD 50 - IP1: $17.5B - TOT: $25B - S08
IP2 RISK REDUCTION NONSTRUCTURAL PARTICIPATION RATE TESTS	
161	NS25IP2 - EADD 50: EASD 50 - IP2: $12.5B - TOT: $25B - S07
162	NS25IP2 - EADD 50: EASD 50 - IP2: $12.5B - TOT: $25B - S08
163	NS25IP2 - EADD 50: EASD 50 - IP2: $10B - TOT: $22.5B - S07
164	NS25IP2 - EADD 50: EASD 50 - IP2: $10B - TOT: $22.5B - S08
165	NS25IP2 - EADD 50: EASD 50 - IP2: $15B - TOT: $27.5B - S07
166	NS25IP2 - EADD 50: EASD 50 - IP2: $15B - TOT: $27.5B - S08
167	NS25IP2 - EADD 50: EASD 50 - IP2: $17.5B - TOT: $30B - S07
168	NS25IP2 - EADD 50: EASD 50 - IP2: $17.5B - TOT: $30B - S08
169	NS5075IP2 - EADD 50: EASD 50 - IP2: $12.5B - TOT: $25B - S07
170	NS5075IP2 - EADD 50: EASD 50 - IP2: $12.5B - TOT: $25B - S08

171	NS5075IP2 - EADD 50: EASD 50 - IP2: $10B - TOT: $22.5B - S07
172	NS5075IP2 - EADD 50: EASD 50 - IP2: $10B - TOT: $22.5B - S08
173	NS5075IP2 - EADD 50: EASD 50 - IP2: $15B - TOT: $27.5B - S07
174	NS5075IP2 - EADD 50: EASD 50 - IP2: $15B - TOT: $27.5B - S08
175	NS5075IP2 - EADD 50: EASD 50 - IP2: $17.5B - TOT: $30B - S07
176	NS5075IP2 - EADD 50: EASD 50 - IP2: $17.5B - TOT: $30B - S08
IP2 RESTORATION TESTS	
177	RESTIP2: $8.5B - S07 ROBUST FREE
178	RESTIP2: $8.5B - S08 ROBUST FREE
179	RESTIP2: $9.5B - S07 ROBUST FREE
180	RESTIP2: $9.5B - S08 ROBUST FREE
2023 DRAFT COASTAL MASTER PLAN ALTERNATIVES	
181	2023 DRAFT CMP - S07, EQUIVALENT TO: 29: ROBUST – IP1: $12.5B – TOT: $22.5B 155: NS75 – EADD 50: EASD 50 – IP1: $12.5B – TOT: $25B – S07 161: NS25IP2 – EADD 50: EASD 50 – IP2: $12.5B – TOT: 25B – S07 177: RESTIP2: $8.5B – S07 ROBUST FREE
182	2023 DRAFT CMP - S08 EQUIVALENT TO: 30: RFREE – IP1: $12.5B – TOT: $22.5B – S08 156: NS75 – EADD 50: EASD 50 – IP1: $12.5B – TOT: $25B – S08 162: NS25IP2 – EADD 50: EASD 50 – IP2: $12.5B – TOT: 25B – S08 178: RESTIP2: $8.5B – S08 ROBUST FREE